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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects. It is intended that the Society should be representative of the profession. Those not engaged in the practice of forestry or the allied sciences are cordially invited to join as Ordinary Members.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

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[continued on inside back cover

FIG. 1. Arrangement of Laths.

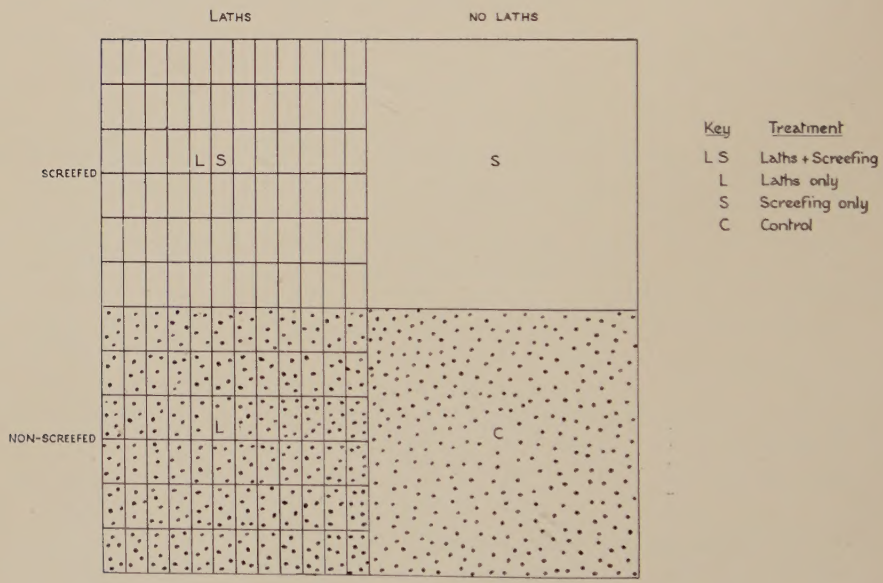

FIG. 2. Experimental layout.

PLATE I

THE INFLUENCE OF ARTIFICIAL SHADING OF THE GROUND VEGETATION ON THE NUTRITION AND GROWTH OF SITKA SPRUCE (*PICEA SITCHENSIS* CARR.) IN A HEATHLAND PLANTATION

By L. LEYTON

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SUMMARY

A marked stimulus has been obtained by shading the heather vegetation surrounding the trees by means of wooden laths. The increased growth was accompanied by significant increases in the concentration of nitrogen, ash, and manganese in the needles, indicating a substantial increase in the availability of these nutrients to the trees. A similar shading experiment on plots from which the heather (*Calluna vulgaris* Hull) had been previously removed by screefing produced only doubtful responses. Heather plants growing beneath the laths were found to contain appreciably lower concentrations of nutrients in the foliage than unshaded plants. Whilst the response of the trees to shading of the ground vegetation is to be attributed largely to reduced competition by the heather for available nutrients in the soil, especially nitrogen, the mulching effect of the heather in maintaining satisfactory moisture conditions during dry periods must also be taken into account. These findings offer an explanation for the improvement in the growth of spruce in mixture with nurse trees when the latter form a closed canopy and suppress the ground vegetation.

INTRODUCTION

THE afforestation of heathland with pure stands of Sitka spruce has presented a number of problems which, despite many years of field experiment, have only been partially resolved. Much of the difficulty lies in the low fertility of these sites, aggravated in many areas by a low rainfall, and the successful establishment of plantations has generally been made possible only by intensive cultivation and manuring. Even then, after a number of years of perhaps reasonable growth, it is not unusual for the trees to show a marked decline in growth rate, often resulting in complete check. This decline more or less coincides with the reinvasion of the planting site by heather, the inhibitory influence of which has been demonstrated, at least indirectly, by the marked response in the growth of the trees following its removal (4, 2). Much of the success obtained in raising spruce plantations in mixture with less susceptible species like Scots pine or Japanese larch might therefore be attributed to the suppression of the heather by shade, especially in view of the observations that the recovery of the spruce from a checked or semi-checked state generally coincides with the formation of a closed canopy by the nurse trees (3). It is not at all certain, however, whether the success of mixed plantations of this kind can be entirely explained in this way, since the nurse species themselves appear to vary appreciably in their efficiency and they may introduce other important environmental changes, e.g. through the particular nature of their litter, which may also influence the growth of the spruce.

The aim of the present investigation therefore was to see whether shading of the heather by means of some inactive material would, under similar conditions, result in a stimulation to the growth of spruce, more or less comparable with that obtained in mixed stands, and to determine if possible the factor or factors underlying this response.

DETAILS OF SITE AND EXPERIMENTAL MATERIAL

The experiment was carried out on an area of pure Sitka spruce, planted in 1942 on Hackness (Broxa) Moor in north-east Yorkshire. The rainfall in this area averages between 25 and 30 inches per annum. The soil is derived from Lower Calcareous Grit (Jurassic) and is typically podzolized with a thin hard ironpan some 6 to 20 inches deep. The dominant vegetation is the heather (*Calluna vulgaris*), and the area represents one of the more difficult sites for afforestation, particularly with Sitka spruce.

Prior to planting, the heather was burnt off and the site prepared by shallow single-furrow ploughing with subsoiling: in the year after planting, basic slag was applied at the rate of 1 ounce per plant. Despite this initial preparation the trees made relatively poor growth and within a few years, as the heather reinvaded the site, were in a state of semi-check.

In 1946 an investigation was made into the effect of removing the heather vegetation from a small area within the plantation and a definite improvement in growth was obtained (for details cf. Weatherell, 1953, Experiment 20). By 1949 the mean height of the trees on the screefed plots was 38·3 inches compared with 30·5 inches on the control plots. The beneficial influence of screefing was still to be observed in 1951 when assessments on 20 trees in each area gave a mean annual increment of $7{\cdot}1 \pm 0{\cdot}7$ inches for the trees on the screefed plots and $3{\cdot}7 \pm 0{\cdot}4$ inches for those on the untreated controls.

In July 1952 both screefed and non-screefed areas were each divided into two halves, one half being retained as a control and the other half covered with a framework of wooden laths, which in the case of the non-screefed plots completely covered the heather, by this time growing most luxuriantly and over 2 feet high. In all the laths surrounded about 40 trees, 20 in the screefed plot and 20 in the heather-covered control plot. The experiment is illustrated in Fig. 1 and details of the layout given in Fig. 2 (Plate I, facing p. 1).

SAMPLING AND ASSESSMENTS

In September 1953, 10 trees were chosen at random from each of the 4 plots and the height of the leading shoot measured for the years 1951, 1952, and 1953. At the same time samples of the current (1953) needles were taken from the uppermost lateral shoots of the trees for subsequent analysis. Samples were also collected of the current foliage of randomly selected *Calluna* plants growing beneath the laths and growing unshaded in the control plot.

The spruce needles and heather foliage were dried in an oven at 105° C. and after grinding in a mill were analysed for nitrogen, phosphorus, ash, potassium, calcium, and manganese. A given number of dried spruce needles were also weighed out to determine the mean dry weight per needle.

RESULTS

Statistical treatment of the data

In all cases the results have been expressed in terms of the mean values for the 10 trees in each plot together with the corresponding standard errors based on the variances within these plots since there is no direct measure of interplot error. The given values will therefore tend to underestimate the standard errors appropriate for comparing plot means, but it is most unlikely that the difference between them will be sufficient to affect either the interpretation of the results or the validity of the conclusions drawn from them.

Height growth and needle dry-weight production

In Table I data are presented for the mean annual height increments in each plot over the period 1951–3 inclusive, and for the mean dry-matter contents of the needles sampled in 1953.

TABLE I. *Sitka spruce. Mean annual height increments for the years 1951, 1952, and 1953 and mean dry weight per needle in 1953*

		Mean annual increment (in.)			*Mean d. wt. per needle*
		1951	*1952*	*1953*	mg.
Screefed plots:	Laths LS	8·2±1·2	6·8±0·8	3·6±0·8	3·6±0·4
	No laths S	6·1±0·7	5·0±0·5	2·0±0·2	3·6±0·2
Non-screefed plots:	Laths L	3·3±0·6	4·1±0·4	7·5±0·7	3·8±0·3
	No laths C	4·0±0·7	4·5±0·5	2·6±0·5	2·6±0·2

As has already been pointed out, the effect of the initial removal of the heather in 1946 is still to be observed in 1951 in the greater height growth on the screefed plots compared with that on the non-screefed plots. Since the laths were not set up until July 1952, by which time the trees had more or less completed their extension growth for that year, any differences in the 1952 increments between the two series of plots must again be attributed solely to this screefing effect. By the end of this growing season, however, the trees growing in the presence of the heather but surrounded by the laths (plot L) were of a much healthier colour than the rather chlorotic looking trees growing in the control plot C. By 1953 the difference in the appearance of the trees from these plots was even more accentuated, and this is reflected in the very striking increase in height growth brought about by shading the heather surrounding the trees. On the other hand, in the absence of a ground vegetation, i.e. on the screefed plots, the lath cover has produced only a doubtful increase in height growth.

The response in needle dry-weight production in 1953 more or less follows that observed in the annual increment. Only in the case of the non-screefed plots does shading result in a significant increase in mean needle weight.

Mineral nutrient status

In Table II data are presented for the mean concentrations of nutrients, expressed as per cent. dry weight, in the needles sampled in 1953.

According to these results there appears to be little doubt that shading the heather surrounding the trees has resulted in a significant increase in the concentration of nitrogen, ash, and manganese in the needle dry weight. Again, as in the case of the growth responses, the effect of the lath cover on the screefed plots

TABLE II. *Sitka spruce. Mean nutrient concentrations in the 1953 needles (per cent. dry weight)*

	%N	%P	%*Ash*	%K	%Ca	%Mn
Screefed plots:						
Laths LS	1·19±0·05	0·080±0·005	3·02±0·17	0·86±0·05	0·50±0·07	0·043±0·005
No laths S	1·06±0·04	0·068±0·002	2·87±0·10	0·83±0·04	0·40±0·03	0·045±0·008
Non-screefed plots:						
Laths L	1·60±0·08	0·127±0·005	3·99±0·21	0·98±0·03	0·56±0·09	0·101±0·003
No laths C	0·72±0·03	0·112±0·006	3·15±0·13	0·98±0·05	0·51±0·05	0·043±0·003

is of doubtful significance. Since in the presence of the heather, shading also results in an increased needle dry weight and shoot growth, this must mean a considerable increase in the uptake of nitrogen, total ash constituents, and manganese by the spruce and, to a lesser extent, an increase in the uptake of the other nutrients even though the concentration of these latter nutrients in the needles remains relatively unchanged. On an absolute basis for example, needles from trees

TABLE III. *The effect of shading on the nutrient concentration in* Calluna *foliage (per cent. dry weight)*

	%N	%P	%*Ash*	%K	%Mn
Under the lath shade .	1·39	0·081	3·54	0·642	0·034
Unshaded . . .	1·88	0·114	5·28	0·905	0·059

growing in the shaded heather contain 62·5±6·6 μg. N and 4·90±0·40 μg. P per needle, whilst those from trees growing in the control plot contain 18·7±1·6 μg. N and 2·93±0·31 μg. P per needle. This represents more than a threefold increase in nitrogen content and almost a twofold increase in phosphorus content.

Although even in 1953 the heather under the laths still appeared to be quite vigorous and healthy, comparative analyses of the current year's foliage reveal an appreciably lower nutrient concentration than in the unshaded plants (Table III). Even if we assume no appreciable loss in dry-weight production under the lath shade, this would still mean a reduced uptake of nutrients by the heather plants in this year.

DISCUSSION OF RESULTS

Whilst there is little doubt that shading the surrounding vegetation considerably stimulates the growth and nutrient uptake of the trees, the factor or factors responsible for this response still remain to be elucidated.

From the data provided by the analyses of the *Calluna* plants and tree foliage it would seem that much of the response could at least be partially explained in terms of a reduced competition for nutrients, particularly for available nitrogen which would appear to be a most important factor limiting tree growth on these heathland soils (2). Attention is drawn to the particularly low concentration of nitrogen in the needles from the control plot C, very suggestive of a nitrogen deficiency. The considerable increase in manganese uptake by the trees, as a result of shading the ground vegetation, is of particular interest since similar responses have been obtained following the application of a heather mulch, a practice which also stimulates nitrogen uptake and tree growth on these sites (2). In the absence of any direct evidence pointing to manganese deficiencies limiting tree growth on these soils, however, it is difficult to decide how much importance should be attached to the increased uptake of this nutrient.

Although reduced competition is therefore of great importance it is very doubtful whether this is the sole explanation for the growth response of the trees, particularly when one considers the relatively poor growth made in 1953 by the trees on the screefed plots where competition by the heather has been completely eliminated. It is of particular interest to note that on these plots the trees show a continued fall in annual increment over the period 1951–3, whereas this is not nearly so marked in the presence of the heather. If we compare the rainfall for these 3 years, we find that over the growing season (May to July) the total precipitation in 1951 was 12·25 inches compared with 6·05 and 7·41 inches for 1952 and 1953 respectively. It would seem therefore that although conditions for spruce growth are potentially better in the absence than in the presence of the heather vegetation, the exposed surface of the soil in the former case tends to render the trees more susceptible to desiccation during dry periods. This is consistent with the very superficial rooting habit of the spruce on these heathland soils. To a certain extent therefore the heather vegetation itself would appear capable of protecting the superficial layer of the soil from excessive desiccation and thus, during a particularly dry year, of actually proving of some indirect benefit to the growth of the spruce. Recent studies on the microclimate of a *Calluna* heathland (1) have revealed a higher humidity and in general a more equable climate at the base of the *Calluna* vegetation than in uncovered ground. If, at the same time, competition by the heather is reduced by shading, then the trees would be expected to show an even greater response and this is what is actually found. Under these conditions the lower and presumably dying shoots of the heather would act as a very effective mulch around the base of the trees, maintaining satisfactory moisture conditions for the trees. This would explain the similarity in the response of the trees to shading of the ground vegetation and actual mulching.

It may be concluded that, apart from any other environmental changes brought

about by nurse trees on these sites, the response of the spruce at the time of the closing of the canopy must be mainly attributed to the suppression of the competing heather vegetation and the formation of an effective mulch around the base of the trees.

ACKNOWLEDGEMENTS

The author is indebted to the Research Branch of the Forestry Commission for their co-operation in providing the necessary facilities for this investigation and to Mr. J. W. Dexter of the Department of Forestry, Oxford University, for his help in the analytical work.

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FOREST ROADS: THEIR ECONOMIC JUSTIFICATION

By H. P. W. HUTSON

SUMMARY

Roads influence the cost of every phase of forestry, but before roads are built in the forest it must be shown that they will pay. The problem is best faced at the start of the life of the forest when planting is being planned since early determination then will ensure that routes built for access and management are on alignments which will later form part of the extraction network. Later, at the beginning of the thinning stage, management may have to decide whether the small mileage already constructed for access is sufficient or whether to add to it to form a full extraction network, i.e. a system of motorable roads close enough spaced to reduce the length and therefore the cost of the very expensive off-the-road haul to a reasonable figure. Three tables are given. The first shows the limiting figure for profitable expenditure on a road network for a range of conditions based on the reduction of the length of off-the-road haul from ½ mile to 150 yards. The second shows the effect of the provision of roads on the investment yield. The third shows roadwork costs per mile and per acre. Using these tables, two typical examples are worked out: one from the point when thinning begins; the other for the entire life of the forest.

A NETWORK of roads in a forest is as much an item of production equipment as a conveyor system in a factory. The conveyor would not be put in unless it could be justified financially. Should not the roads be looked at similarly? One cannot expect money to be found for their construction unless the return from this expenditure is shown to be worth while.

It is unfortunate that there is no generally accepted method of setting out a case for forest roads. The existence or absence of roads influences the cost of practically every phase of forestry—the establishment of a plantation, its management and protection and, of course, the harvesting of the crop—but the apportionment of the roadwork charges between these phases and the operations involved is not readily calculable, whilst an assessment showing the road expenditure per unit of the total crop although easily calculable will tell us nothing of what is to be gained by having the roads and is therefore no yardstick by which to judge whether or not to build them.

The need for determining the worth of forest roading is most likely to arise when a forest is at one or other of two stages in its existence. It might be at the start of the life of the forest when the planting is being planned, since it is at this time, when the ground is clear of trees, that the road layout can be prepared with the least difficulty, and an early determination in this fashion of the road system is most desirable if the routes built for access and management are to be on alignment which will later form part of the extraction network. Alternatively there is the case of the forest which is approaching the thinning stage and which already possesses a small mileage of roads, no more probably than what has just sufficed for the original planting and subsequent management. The question here will be whether to leave the roading as it is or to add to it so as to form a full extraction network.

This full extraction network ought perhaps to be explained. Briefly, it means

a system of motorable routes closely enough spaced to keep the off-the-road haul to its lowest practicable length. This off-the-road haul or initial movement of the produce from the stump is the most costly part of the extraction process as well as the most demanding in man-power. Compared with movement by road its cost is often 200 times as great—the reckoning has to be in pounds instead of pence—and its man-power requirement may be 1,000 times that of the other. It cannot be eliminated, but it can and should be kept to a minimum. Logging opinion seems fairly unanimous that 150 yards or thereabouts ought to be the limit for the drag from the stump. With distances greater than this the cost curve tends to rise steeply. Horse-drag, which has for long been the principal means of movement from the stump, is the basis for this assessment. There are difficulties nowadays in obtaining horses for extraction and even more in getting the men to work them. Consequently tractors are being increasingly used instead. The close spacing of the trees during the early thinnings will, however, impose limitations of size on the machines and this, together with the complications of bundling the poles, will keep down pay loads and therefore the economic distance of haul. Probably the 150 yards limit for horse drag will stand for the tractors as well.

To obtain this 150 yards limit the roads throughout the forest can be no farther apart than 300 yards. This spacing assumes that the configuration of the ground and the going will allow the timber to be fed to a road from both sides. Feeding in this way from both sides is probably possible more often than not, but places where the slopes are too steep or too difficult for work in both directions are by no means infrequent and in such situations the 300-yard intervals might have to be halved. The mileage necessary to give the 300-yard spacing amounts to some 7 miles per square mile of forest which is equivalent to 19 yards of road per acre. Where the spacing has to be halved the 19 yards would have to be increased to 33. When we speak of a full extraction network therefore we mean a roading system amounting normally to 19 yards per acre but thickened to 33 where feeding is only possible from one side. With this network the off-the-road haul will not exceed 150 yards.

Let us consider first the case of a forest or forest area which is nearing the thinning stage. In this situation the simplest way of justifying the provision of the full network will be by comparing the return to be got from the forest when it has the network with what it would be without it. The forest in the latter case is unlikely to be altogether devoid of roads. Some vehicle routes will almost certainly have been provided for access and management and must be allowed for. Experience suggests that 1 mile per square mile of forest (i.e. 3 yards to the acre) is a reasonable density for these purposes and we will make our comparison on this basis. The full network, as we have shown, keeps the off-the-road movement down to 150 yards: with the thin density of only 3 yards to the acre, distances up to ½ mile would be normal and would rise to 1 mile where the produce could be fed on to the road from only one side. Our problem now is to determine to what extent the savings to be expected from the shorter and therefore cheaper off-the-road movement obtained with the full network will outweigh the charges incurred in providing and maintaining the additional roads.

At the time we have taken for this comparison, i.e. when the forest is 15–20 years old, it should not be difficult to make a reasonable assessment of its likely yield, taking into account the qualities and stockings of the various stands and obtaining the average mean annual increment for the whole area. Figures should also be available from local or other experience for the costs of road construction in the forest and also for off-the-road haul. This last item of information we shall want in two parts: the cost for a haul of 150 yards by horse or tractor according to which it is intended to employ, and the cost for ½ mile, again by whatever method or combination of methods, e.g. horse drag followed by tractor drag, appears most suitable. It is the difference between the costs over these two distances (or between those for 150 yards and 1 mile where the latter would be the length of haul to the road) that we need for our calculations.

These calculations are quite simple. Starting with the difference in cost between the 150-yard and the ½-mile (or 1-mile) hauls, we work out the saving per acre for each of the thinning crops in a rotation and also for the main crop. Each of these amounts is then discounted at the ruling rate of interest to the year for which the comparison is being made. Their total, less a deduction to meet road maintenance charges, shows the sum of money per acre which could be used to provide the 16 or 30 yards as the case may be of the full network. So long as the cost of the network is kept within this sum extraction by means of the network will be cheaper than without it. Table I shows the limiting road-construction figures per acre for a series of extraction-cost differences ranging from 1*d.* to 1*s.* per cubic foot in forests having average mean annual increments from 85 to 200. It also gives the road-construction costs per mile corresponding to the figures per acre. The method of calculation is illustrated by an example given in Appendix I together with some figures of road costs and yields which may be useful in making other comparisons.

The method outlined will show clearly enough whether the full network would be an economy or not. The amount of the saving will be the difference between the permissible or limiting road-construction expenditure per acre and the estimated likely expenditure, the latter figure being obtained by converting the estimated cost per mile into the equivalent cost per acre (see Table III).

We will now turn to a forest which is in its earliest days with the planting up being planned. Ahead lies first what is known as the establishment stage, during which the land is fenced and drained, ploughed if need be, and planted up. This is followed by a period of maintenance which lasts until the crop is ready for thinning. The thinning is done successively, at intervals probably of 3 to 5 years, until the end of the rotation, when the final or main crop is harvested. In every one of these stages and in almost every operation which takes place during them the existence or want of roads will be a factor affecting costs and in consequence profits. And since roads cannot be provided at short notice either satisfactorily or economically and their siting moreover, if settled in time, may be combined advantageously with other features of the forest layout—e.g. compartment boundaries, fire rides, drains—it is clearly necessary to consider the roads with the rest of the forest planning. The expenditure on roads and the stage or stages in which

TABLE I. *Limiting figures for profitable expenditure on road network*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			Limits of Profitable Roadwork Expenditure					
			70-year rotation			*50-year rotation*		
M.A.I.	*Yield*	*Difference in costs (d.)*	£/acre	£/mile (16 yds./acre)	£/mile (30 yds./acre)	£/acre	£/mile (16 yds./acre)	£/mile (30 yds./acre)
85	*70-year rotation:* 10 thinnings, each 210 / Maincrop 3,840	1	5·52	..	..	6·46	150	..
		2	11·05	550	50	12·92	850	250
		3	16·57	1,100	400	19·39	1,600	650
		4	22·10	1,800	700	25·85	2,300	1,000
		5	27·62	2,400	1,000	32·31	3,000	1,400
		6	33·15	3,000	1,350	38·77	>3,000	1,800
		7	38·67	>3,000	1,650	45·23	,,	2,150
	50-year rotation: 6 thinnings, each 210 / Maincrop 3,030	8	44·20	,,	2,000	51·70	,,	2,550
		9	49·72	,,	2,250	58·16	,,	2,900
		10	55·25	,,	2,500	64·62	,,	>3,000
		11	60·77	,,	2,800	71·08	,,	,,
		12	66·30	,,	>3,000	77·54	,,	,,
100	*70-year rotation:* 10 thinnings, each 250 / Maincrop 4,500	1	6·76	90	..	7·75	300	..
		2	13·53	800	200	15·50	1,150	400
		3	20·29	1,600	600	23·25	2,000	900
		4	27·05	2,300	1,000	31·00	2,850	1,300
		5	33·81	3,000	1,400	38·75	>3,000	1,800
		6	40·58	>3,000	1,800	46·51	,,	2,250
	50-year rotation: 6 thinnings, each 250 / Maincrop 3,500	7	47·34	,,	2,200	54·26	,,	2,700
		8	54·10	,,	2,600	62·01	,,	>3,000
		9	60·87	,,	2,900	69·75	,,	,,
		10	67·63	,,	>3,000	77·50	,,	,,
		11	74·69	,,	,,	85·25	,,	,,
		12	81·16	,,	,,	93·00	,,	,,
125	*70-year rotation:* 10 thinnings, each 310 / Maincrop 5,650	1	8·42	250	..	9·67	500	80
		2	16·85	1,200	400	13·35	1,600	650
		3	25·27	2,100	900	29·02	2,650	1,200
		4	33·70	3,000	1,400	38·70	>3,000	1,800
		5	42·12	>3,000	1,900	48·37	,,	2,350
		6	50·54	,,	2,400	58·04	,,	2,900
		7	58·97	,,	2,900	67·72	,,	> 3,000
	50-year rotation:	8	67·39	,,	>3,000	77·36	,,	,,
		9	75·82	,,	,,	87·03	,,	,,

	6 thinnings, each 310 Maincrop 4,390	10	84·24	,,	,,	96·70	,,	,,
		11	92·66	,,	,,	106·37	,,	,,
		12	101·07	,,	,,	114·04	,,	,,
		1	10·15	450	..	11·64	700	200
	70-year rotation:	2	20·31	1,550	600	23·27	2,000	900
		3	30·46	2,700	1,200	34·91	>3,000	1,550
	10 thinnings, each 375 Maincrop 6,750	4	40·61	>3,000	1,800	46·55	,,	2,250
		5	50·76	,,	2,400	58·18	,,	2,900
150		6	60·92	,,	3,000	69·82	,,	>3,000
		7	71·07	,,	>3,000	81·48	,,	,,
	50-year rotation:	8	81·20	,,	,,	93·12	,,	,,
		9	91·35	,,	,,	104·76	,,	,,
	6 thinnings, each 375 Maincrop 5,250	10	101·50	,,	,,	116·40	,,	,,
		11	111·65	,,	,,	128·04	,,	,,
		12	121·80	,,	,,	139·68	,,	,,
		1	13·54	800	200	15·42	1,150	400
	70-year rotation:	2	27·07	2,300	1,000	30·83	2,800	1,300
		3	40·61	>3,000	1,800	46·25	>3,000	2,200
	10 thinnings, each 500 Maincrop 9,000	4	54·14	,,	2,600	61·66	,,	>3,000
		5	67·68	,,	>3,000	77·10	,,	,,
200		6	81·22	,,	,,	92·52	,,	,,
		7	94·75	,,	,,	107·94	,,	,,
	50-year rotation:	8	108·29	,,	,,	123·36	,,	,,
		9	121·82	,,	,,	138·78	,,	,,
	6 thinnings, each 500 Maincrop 7,000	10	135·36	,,	,,	154·20	,,	,,
		11	148·84	,,	,,	169·62	,,	,,
		12	162·43	,,	,,	185·04	,,	,,

(1) M.A.I. = Average mean annual increment in hoppus feet over bark.
(2) Yield = Estimated crops in cubic feet per acre, the thinning crops being averaged.
(3) Difference in costs = Difference between cost of haul over 150 yards (i.e. *with* road network) and that of haul of ½ mile (i.e. *without* road network).
(4) and (7) £/acre = Saving resulting from difference in costs discounted to the present time.
(5) and (8) £/mile (16 yds./acre) = Limiting unit cost of road construction which will provide network of density 16 yds./acre within above saving allowing deduction for maintenance of the network at £0·3 per acre per year.
(6) and (9) £/mile (30 yds./acre) = Limiting unit cost of road construction which will provide network of density 30 yds./acre within above saving allowing deduction for maintenance of the network at £0·5 per acre per year.

it should be incurred are factors to be taken into account with the establishment and other charges if a proper assessment of the scheme is to be made and an estimate obtained of the likely return from the money invested.

There are doubtless many ways by which the financial prospects of a forestry project might be assessed. The method which follows deals with the roadwork in detail, but keeps it, none the less, as a part of the whole project. Roads are the particular concern of this paper, but because of their all-pervading effects, they cannot be considered in isolation. Their background must be the whole forestry project from the acquisition and preparation of the ground to the harvesting of the main crop at the end of the rotation. Our procedure will be, as it was with the first case when we took the forest at the thinning stage, to compare results with and without the full road network. Now, however, these results will take into account not only the roadwork costs but all the other expenditure involved in the establishment and growth of a forest to maturity. They will be expressed as percentage yields on the money required to establish the forest. This will give us a simple comparison showing at once the effect of the roadwork expenditure in its proper setting.

It will be convenient to group the data for our calculations under the three heads—establishment, maintenance, and extraction including roadwork. These three categories make up the production picture. In the end we shall have to look at them all together, but our calculations will be simplified if we deal with them successively, starting with the extraction and roadwork category. The calculation involves no abstruse formula: it is merely a matter of compiling a running account of the estimated expenditure and interest charges and setting against these the estimated receipts as they are obtained, thus gradually amortizing the debits and so, after allowing for the harvesting of the main crop, finally arriving at the figure of the overall profit (or loss). Because we are taking the three heads separately the amortization will be applied first to the roadwork charges, then to those under the maintenance head, and lastly to the establishment charges.

This paper is not the place for lengthy calculations. An example, somewhat abridged, will be found at Appendix II. It gives the steps in the calculation. The result, in the particular example, shows that provision of the full network would increase the yield on the investment by $\frac{3}{8}$ per cent. The management now has a factual economic basis for deciding their road plan. Where a number of projects have to be considered, tables covering the likely ranges of the different variables can be drawn up. Table II is an illustration. It has been calculated for the same data as were used for the example in Appendix II. By having figures showing in one table the effects of changes in the more important variables the most suitable combination can be chosen. In this way silvicultural factors can be properly conditioned to economics.

APPENDIX I

Will a Full Extraction Network be Worth While?

Example

A forest area assessed at average mean annual increment 100 (hoppus measure over bark) and 70-year rotation is to receive its first thinning in its 20th year. The existing roading is

Table II. *Effect of roading on investment yield*

Density of roading	*Minimum (3 yds./acre)*									*Full network (minimum plus 16 yds./acre)*								
Cost of road construction	*£2,000 per mile*									*£1,000 per mile*			*£1,500 per mile*			*£2,000 per mile*		
Extraction cost (Pence/cub. ft.)	*9*			*12*			*15*			*6*			*6*			*6*		
Establishment charge (£/acre)	*30*	*40*	*50*	*30*	*40*	*50*	*30*	*40*	*50*	*30*	*40*	*50*	*30*	*40*	*50*	*30*	*40*	*50*
	Yield per cent. on establishment charges																	
70-year rotation:																		
M.A.I. 100	3 13/16	3 3/8	3 1/16	3 1/8	2 11/16	2 3/8	1 5/8	1 1/4	7/8	3 7/8	3 3/8	3 1/16	3 5/8	3 1/8	2 7/8	3 3/8	3	2 5/8
,, 125	4 5/8	4 1/8	3 3/4	4 1/16	3 5/8	3 5/16	3 1/4	2 13/16	2 1/2	4 5/8	4 1/4	3 7/8	4 1/2	4 1/8	3 3/4	4 3/8	4	3 5/8
,, 150	5 1/8	4 3/4	4 3/8	4 11/16	4 1/4	3 7/8	4 1/4	3 13/16	3 7/16	5 3/16	4 3/4	4 7/16	5 1/8	4 11/16	4 5/16	5	4 5/8	4 1/4
,, 200	5 3/4	5 3/8	5	5 3/8	4 15/16	4 5/8	5	4 9/16	4 1/4	5 13/16	5 1/2	5 1/8	5 3/4	5 7/16	5 1/8	5 3/4	5 3/8	5
50-year rotation:																		
M.A.I. 100	3 7/8	3 5/16	2 7/8	2 7/8	2 1/4	1 13/16	Less than 1			4 1/16	3 1/2	3	3 7/8	3 1/4	2 13/16	3 5/8	3	2 9/16
,, 125	4 7/8	4 1/4	3 13/16	4 1/16	3 1/2	3	2 13/16	2 1/4	1 3/4	5 1/16	4 1/2	4	4 15/16	4 5/16	3 7/8	4 3/4	4 3/16	3 11/16
,, 150	5 5/8	5	4 9/16	4 7/8	4 1/4	3 3/4	4 1/8	3 1/2	3	5 3/4	5 1/8	4 11/16	5 5/8	5 1/16	4 5/8	5 9/16	5	4 1/2
,, 200	6 7/16	5 13/16	5 3/8	5 5/8	5 1/4	4 3/4	5 1/8	4 1/2	4	6 11/16	6 1/16	5 5/8	6 5/8	6	5 9/16	6 9/16	6	5 1/2

only 3 yards to the acre and off-the-road haul to it would cost 10*d.* per cubic foot whereas the rate for a haul of 150 yards would be 5*d.* The estimated cost of the additional roading is £1,700 per mile. Over 25 per cent. of the area the spacing would have to be 150 yards: over the remaining 75 it would be 300 yards.

Taking the 5*d.* difference in the costs of the off-the-road movement, the savings to be made at each thinning and on the main crop (see Table I for yields corresponding to average M.A.I.) are calculated, discounted at the current rate of interest (4½ per cent.) to the present time (year 20) and totalled as follows:

M.A.I.	*Year*	*Crop (cub. ft.)*	*Value of saving at 5d. cub. ft.* £	*Years at discount*	*Amount at year 20* £
100	20	250	5·2	0	5·200
	25	,,	,,	5	4·170
	30	,,	,,	10	3·350
	35	,,	,,	15	2·690
	40	,,	,,	20	2·160
	45	,,	,,	25	1·730
	50	,,	,,	30	1·390
	55	,,	,,	35	1·110
	60	,,	,,	40	0·895
	65	,,	,,	45	0·715
	70	4,500	93·75	50	10·405
				TOTAL	33·815

From this total of £33·815 a deduction has to be made to cover the cost of maintaining the extraction routes. Three-quarters of the area is being roaded at the 16 yard/acre density, requiring therefore 12 yards, and one-quarter at 30 yards/acre, requiring 7½, making the total mileage 19½ yards/acre. The maintenance charge for this, taking the figures from Table III, item (*c*), and interpolating to obtain a value for 19½, would be about £0·36 per acre per year. It has to be met over the years 21 to 70. Its present value at 4½ per cent. is £7·115. Making the deduction, then

	£
	33·815
less	7·115
we get	£26·700

this balance being the amount per acre which would just offset our 5*d.* saving, i.e. the limit within which the cost of constructing the roads must be kept if the full network is to give the more economical extraction. The estimated road construction cost is £1,700 per mile, representing £2·9, £15·3, and £28·9 for 3, 16, and 30 yards per acre respectively; *vide* Table III. Our example calls for 19½ yards, i.e. £18·7 per acre. In this case therefore the full network is justified and should mean a saving of £8 per acre.

APPENDIX II

Estimating the Financial Prospects of an Afforestation Project

Example

A project for planting up a newly acquired area is under consideration. Estimates of the various charges likely to be incurred and other information is as follows:

(*a*) Establishment charge: £45 per acre. This sum will cover fencing, ploughing for

planting, and drainage, planting including the cost of the plants, beating up, and weeding and also the cost of acquiring the land (i.e. either the interest on the purchase price or the rent if the land is rented). It is assumed that this is the expenditure which will be incurred during the first 5 years of the life of the forest. Roadwork is NOT included—see (*c*).

(*b*) Maintenance charge: £1·75 per acre per year for years 6–20 and £1 per acre per year for the remainder of the rotation. These figures are for forest maintenance, NOT for road maintenance—see (*c*).

TABLE III. *Roadwork costs per mile and per acre*

Item	*Unit cost* (£/*mile*)	*Cost per acre of forest* — *Yards of road per acre* 3 (£/*acre*)	16 (£/*acre*)	30 (£/*acre*)
(*a*) New construction	100	0·17	0·91	1·70
	200	0·3	1·8	3·4
	300	0·5	2·7	5·1
	400	0·7	3·6	6·8
	500	0·8	4·5	8·5
	600	1·0	5·4	10·2
	700	1·2	6·3	11·9
	800	1·4	7·2	13·6
	900	1·5	8·1	15·3
	1,000	1·7	9·0	17·0
	1,250	2·1	11·2	21·2
	1,500	2·6	13·5	25·5
	1,750	3·0	15·7	29·7
	2,000	3·4	18·0	34·0
	2,250	3·8	20·2	38·2
	2,500	4·2	22·5	42·5
	2,750	4·7	24·7	46·7
	3,000	5·4	27·0	54·0
(*b*) Maintenance—applicable to routes in regular use throughout the year	100 per year	0·2 per year	..	..
(*c*) Maintenance—applicable to extraction routes under intermittent traffic	30 per year	..	0·3 per year	0·5 per year

(*c*) Cost of road construction: £2,000 per mile with maintenance costs as in Table III, items (*b*) and (*c*). The requirement for access and management will be 3 yards per acre. Nothing more will be wanted until extraction starts, when an additional 16 yards per acre would give a full network.

(*d*) It is considered that a crop having an average mean annual increment of 150 cubic feet (hoppus measure over bark) can be grown and that the rotation will be 70 years, with the first thinning between years 20 and 25. The yield corresponding to this estimated M.A.I. and rotation will be 10 thinning crops at 5-year intervals, averaging 375 cubic feet each and a maincrop of 6,750 cubic feet.

(*e*) Rate of interest is 4½ per cent.

We start the calculation with the extraction head which includes the roadwork. During the first 20 years there will be no receipts from produce and the initial charge due to the

access and management roads will have been accumulating at compound interest. If the full network is to be provided the work should be done so that the roads are ready in time for the first thinning, i.e. the construction should take place between years 15 and 20. It is at year 15 therefore that the project could proceed either with the minimum roading or with the full network. Our calculation must show which course would be more advantageous.

1. *By year 15* the charge due to the construction of the minimum roading plus the interest on this for 15 years together with the yearly maintenance charge, again with interest would amount to £10·737 per acre.

2. *By year 20* the amount in (1) would have increased to £14·472 or £36·903, depending upon whether the roading is left as it is or is increased to the full network.

3. *Period 20–70 years*: thinnings will be extracted every 5 years.

Assumptions have to be made both for the extraction costs and for the prices obtained for the produce. As regards the latter the following figures will be taken:

	s.	d.
1st, 2nd, 3rd thinnings, delivered at roadside: per cubic foot . .	1	9
4th " " " . .	2	0
5th and 6th " " " . .	2	3
7th and 8th " " " . .	2	6
9th " " " . .	2	9
10th " " " . .	3	0

The extraction cost—averaged over the whole crop—is put at 6*d*. per cubic foot where the off-the-road haul is kept down to 150 yards, i.e. where the full network is provided, and at 1*s*. where the minimum roading is left and the haul consequently extends up to ½ mile. The extraction includes felling, limbing, and movement from stump to roadside.

Continuing from (2) our calculation proceeds in 5-year steps, the receipts less extraction costs being set against the charge which has already accumulated as well as the current interest and road maintenance charges. As soon as the roadwork expenditure has been amortized and the current maintenance charges (forest and road) can be met from income, the early forest maintenance charge—vide (*b*) above—which has been accumulating at interest since year 6 is brought into the account and gradually paid off. And so our calculation reaches year 70, when all the thinnings have been extracted. The positions in the two cases we are examining will be:

4. *At year 70*

With minimum roading only: Charge £29·094 per acre.
With full network: Profit £9·843 per acre.

In other words, the forest with the full network would have more than paid off the roadwork charges and also those for forest maintenance, whilst the other still shows a debit.

With the harvesting of the final crop—which we will assume is sold at 3*s*. 3*d*.—the positions become:

With minimum roading: Profit £730 per acre.
With full network: Profit £940 per acre.

Turning back to our original investment—£45 per acre spent on establishing the forest—we see that in terms of yield on this investment the projects compare as follows:

With minimum roading: yield = $4\frac{1}{16}$ per cent.
With full network: " = $4\frac{7}{16}$ per cent.

THINNING GRADES BASED ON THE THICKNESS OF ANNUAL RINGS[1]

By W. E. HILEY and R. LEHTPERE

SUMMARY

This paper propounds a new method of calculating numerical thinning schedules for conifers which are designed to give, on the average, any reasonable pattern of ring width at breast height in the 100 largest trees in a plantation. It starts from the Forestry Commission's *Revised Yield Tables for Conifers in Great Britain* and is based on the principle that, if the current annual increment in a plantation is unaffected by the grade of thinning, the ring widths must be inversely proportional to the bole area per acre, i.e. the total area of cambium on the main stems of the trees. Sources of error in the method of calculation are discussed, and it is considered that such errors are not so serious as to endanger the use of the method as a means of calculating approximate thinning schedules. As an approximate yield table can be constructed for each thinning grade, the method can be used to estimate the relative costs of growing trees of various diameters with various ring width patterns.

1. INTRODUCTION

THE *Revised Yield Tables for Conifers in Great Britain* by Hummel and Christie (8) contain sets of figures which enable us to visualize the effect of a thinning grade in a new and realistic manner. They show the mean breast height quarter girth of the 100 largest trees at each thinning and, by following the rate of increase in girth, we can work out the number of annual rings to the inch which these trees put on in each thinning period. The 100 largest trees are representative of the dominant trees in a plantation and, if the thinning is from below, they will, with some exceptions, be the same 100 trees from beginning to end. So the calculated ring widths at successive ages give us a picture of what a cross-section at breast height through a dominant tree will look like at the end of a rotation. We can then decide whether this is the kind of tree we want to grow or, in other words, whether the thinning grade depicted in the yield table is the one we want to follow. The thinning grades which are adopted in the yield tables are the same as those which are recommended, although somewhat tentatively, in the second edition of *The Thinning of Plantations* (3).

The average numbers of rings per inch which are put on in each decennial period in the growth of the various species are shown in Table II, from which it

[1] In order to enable readers to follow the calculations in this paper the abbreviations employed are here explained in alphabetical order.

B = bole area equivalent ($n \times b \times g_m$).
C.A.I. = current annual increment.
C, D = thinning grades.
g_m = mean breast height quarter girth.
g_{100} = mean breast height quarter girth of 100 largest trees per acre.
b = mean height.
n = number of trees per acre.
R = number of annual rings per inch.

will be seen that the ring widths become smaller with increasing age, and that in all species except Norway spruce the fall off is rapid. We should ask ourselves whether it is desirable to grow trees with such narrow rings, and whether it might not be better to design our thinning schedules so that the dominant trees would grow faster and become thicker in a given time. We know that about seven rings to the inch is enough in conifers for satisfactory strength[1] and, although narrower ringed timber is preferred for joinery work, it requires a very long rotation and is very expensive to grow.

Apart from the famous instance in South Africa, where Craib (2) worked out that, on first-quality sites, *Pinus patula* might be grown to 18 inches diameter breast height in 30 years and designed a thinning schedule to produce this size, we know of no case in which a thinning grade has been devised to lead to a stated type of final crop. In this paper a method is explained by which a numerical thinning schedule can be designed to produce any pattern of ring widths in the dominant trees which is within the capacity of the species and the site; and, although we cannot be confident that it will work out accurately in practice, we hope that it will do so within reasonable limits of error. If this or some other method of relating thinning grades to ultimate yields were found to work, an important new field in forest economics and management would be opened up. When the number of trees per acre and their mean quarter girth have been determined for any thinning grade, as in Table IV, an approximate yield table can readily be constructed to run in parallel with the corresponding Forestry Commission yield table. And a series of such tables would enable us, by a method previously explained by one of us (4), to calculate the *relative* average costs, on any given site quality, of growing trees of various sizes and containing annual rings of various widths. Parallel research in the saw-milling industry might show the relative costs of sawing logs with various diameters and the relative values of the products. We should then have a scientific basis for developing a timber industry which could compete on the best available terms with imported timber.

This may appear to be a very distant objective, but we must remember that something approaching it has already been achieved in South Africa. Many foresters may be content to continue with our present hit-or-miss methods of thinning; if so, they should study the figures in Table II. This table shows the results of thinning plantations in accordance with the latest recommendations of the Forestry Commission, but to us it appears quite unreasonable that in Britain, where our main endeavour must be to build up supplies of saw timber as quickly as possible, we should be content with such slow rates of diameter growth.

The question of how to thin is our most pressing problem and we cannot wait until, many decades hence, the results of experimental tests may demonstrate the reactions of trees to various thinning methods. We have to take a chance in any case, and it is far better to use the results of mathematical calculations than to plunge blindly. A thinning grade is never a very exact recipe and an error of 10 per cent. is hardly noticeable; when a thinning grade prescribes 400 trees to the acre, any plantation which has 440 or 360 is near enough; and if any forester aimed at

[1] C. J. Chaplin *et al* (1).

7·0 rings to the inch and secured 7·7 rings he would rightly consider himself to be remarkably successful.

In the example which is here selected for demonstrating the new method we attempt to devise a thinning schedule for Corsican pine, quality class II, which will allow the dominant trees to grow at an average rate of 7·0 rings to the inch from the 20th to the 50th year. The result of the calculation is that, after the thinning at 50 years, the crop will be composed of about 70 trees to the acre with a mean b.h.q.g. of 13½ inches and a volume per acre of about 3,100 h.ft.o.b. The new Forestry Commission yield table has 255 trees to the acre at this age with a mean b.h.q.g. of 8¾ inches and a volume of 4,420 h.ft.o.b. The 100 largest trees will have a b.h.q.g. of 10 inches. Owing to their larger size the 70 trees in the heavily thinned plot would probably be worth about as much at present prices as the 255 smaller trees in the yield tablg plot, and the intermediate income from thinnings would be much higher. A money yield table has been constructed for the heavy thinning and it appears that, using the price gradient on page 277 of *Woodland Management* (5), which allows a net o.b. price of about 1*s*. per h.ft. at 6 inches b.h.q.g. rising to 2*s*. at 14½ inches, a stand worked under the new thinning grade would earn compound interest at a rate of 4·7 per cent. compared with 3·9 per cent. with Forestry Commission yield table. The difference is very significant.

It is not maintained that this is the *right* way to thin Corsican pine. It might be better to allow the ring width to fall off gradually from 7·0 rings to the inch at 20 years to 9·0 rings at 50 years, and it would be just as easy to calculate a thinning régime to match this rate of growth. There would then be about 100 trees to the acre at 50 years (after thinning) with a mean b.h.q.g. of a little less than 12 inches. This might be preferred because there is some doubt whether 70 trees to the acre would be sufficient to provide full canopy; nevertheless, we think that, if a crop were educated along the lines indicated in the new thinning schedule, the crowns would be sufficiently vigorous to join up. With such heavy thinning artificial pruning is desirable.

A method of calculating thinning grades was suggested on page 283 of *Woodland Management* (5). The method described in this paper is based on somewhat different principles but the results of the two methods are found to be substantially the same.

2. RINGS PER INCH

The formula for ascertaining the number of rings per inch from two successive measurements of a tree is worked out in the Appendix, where it is shown that, if R equals the number of rings per inch put on during an interval,

$$R = \sqrt{\left(\frac{100}{100-\text{bark }\%}\right)} \times \frac{\pi}{2} \times \frac{\text{interval in years}}{\text{increase in q.g.}}.$$

In Corsican pine the average bark per cent. is 19 (9), so the formula reduces to

$$R = 1{\cdot}75 \frac{\text{interval in years}}{\text{increase in q.g.}},$$

and applying this formula to the 100 largest trees in the yield table for Corsican pine, quality class II, we get the series of figures shown in column (3) of Table I. The figures in this column are very irregular because the quarter girths are recorded only to the nearest quarter of an inch. In column (4) the quarter girths have been smoothed, and these new values give the fairly regular progression of rings per inch shown in column (5).

These, then, are the average ring widths which we may expect to find in the dominant trees in a Corsican pine, qu. cl. II, plantation grown in accordance with

TABLE I. *Corsican pine, qu. cl. II. Rings per inch in 100 largest trees per acre*

Age (years)	*Mean q.g. of 100 largest trees (in.)*	*No. of ann. rings per inch*	*Mean q.g. (smoothed) (in.)*	*No. of ann. rings per inch*
(1)	(2)	(3)	(4)	(5)
20	5¼		5·30	
		7·0		8·1
23	6		5·95	
		10·5		9·2
26	6½		6·52	
		9·3		10·4
30	7¼		7·19	
		11·6		11·5
35	8		7·95	
		11·6		12·5
40	8¾		8·65	
		17·5		13·5
45	9¼		9·30	
		11·6		14·6
50	10		9·90	

the thinning schedule on which the yield table is based. Since some years are more favourable for growth than others there is likely to be some irregularity in ring widths and the progression will not be followed exactly; but the ring widths will tend to fall off in the manner shown and, if the plantation follows the rate of growth shown in the yield table, the 100 largest trees will have an average b.h.q.g. of 10 inches at 50 years and the outermost annual rings will be about $\frac{1}{15}$ inch in thickness.

Table II shows the number of rings per inch at breast height in the 100 largest trees in three quality classes of each of seven species covered by the yield tables. They are worked out in the same way as those in column (5) of Table I, but cover successive periods of 10 years in the growth of plantations in place of the irregular thinning periods which are displayed in the yield tables. In each case the quarter girths have been plotted against age and a smooth curve has been drawn through the points; there is always an element of doubt in drawing the curve, especially at the two ends, so no great accuracy is claimed for the figures in the table.

TABLE II. *Number of rings per inch in the 100 largest trees*

(Figures calculated from *Revised Yield Tables for Conifers in Great Britain* after smoothing quarter girths)

Species	*Scots pine*			*Corsican pine*			*European larch*			*Japanese larch*			*Norway spruce*			*Sitka spruce*			*Douglas fir*		
Quality class	I	II	IV	I	II	IV	I	III	V	I	III	V	I	II	IV	I	III	V	I	III	V
Age (years)																					
20–30	8·5	9·4	..	9·2	9·3	..	10·6	11·7	..	9·0	10·3	15·5	8·2	9·7	..	5·4	7·1	8·8	6·0	6·4	7·3
30–40	8·5	9·4	17·0	9·2	12·0	15·2	13·6	16·2	21·2	11·4	12·2	18·0	8·2	9·7	16·5	7·9	7·9	8·8	8·5	8·3	8·1
40–50	9·4	10·6	17·0	11·7	14·0	16·6	16·2	22·7	28·3	14·9	16·3	21·4	9·4	9·7	16·5	13·8	11·1	10·3	11·0	11·0	11·8
50–60	12·1	12·6	17·0	..	..	..	20·0	30·9	30·1	..	..	..	..	..	..	..	..	..	..	..	..
60–70	15·4	16·2	17·9	..	..	..	26·1	37·8	35·0	..	..	..	..	..	..	..	..	..	..	..	..

3. THE INFLUENCE OF THINNING ON THE C.A.I.

It is assumed in the calculations that the current annual increment of a coniferous plantation is not materially influenced by the grade of thinning. It is widely believed that this is true, though the Bowmont plots of Norway spruce near Kelso in Scotland appear to show that heavy thinning increases the C.A.I. (6), (5). In this series of permanent sample plots there are four replications of each treatment and the total yield under a D thinning is significantly higher than that under a C thinning, which, again, is higher than that under a B thinning. Encouraged to hope that this result might apply generally, we examined the results of measurements in a long series of comparative thinning plots maintained by the Forestry Commission[1] and found that, though in some cases heavy thinning was associated with a heavier total yield, in others it accompanied a reduced yield. The outstanding impression derived from this examination is the extraordinary waywardness of the growth of plantations.

In Wiedemann's yield tables for moderate and heavy thinning (11) the total yield is not significantly affected by the grade of thinning in beech or Scots pine, but with Norway spruce heavy thinning appears to give a somewhat higher total yield at 60 years but a lower one at 120 years.

4. THE BOLE AREA

A heavy thinning leaves fewer trees in a plantation than a light thinning; it consequently reduces the total area of cambium on the main stems of the trees standing on an acre. If, during the subsequent 5 years, this smaller area of cambium puts on the same volume increment as the larger area of cambium which remains in a less heavily thinned plantation, it must make broader annual rings. We know, of course, that it does so; but the important point in the present argument is that, *on the average, the width of the annual rings must be inversely proportional to the area of the cambium.*[2]

Bert Lexen (10) introduced the term *bole area* to designate the area of cambium on the main stem of a tree, and showed that it was approximately equal to $D \times H/k$ square feet, where D is the breast height diameter in inches, H the total height in feet, and k is a factor which is fairly constant for any one species and, for the coniferous species which he examined, varies between 6·6 and 7·5. The value of k is dependent on the tree form and taper. In this paper we are dealing with the bole area of an acre of plantation and we are concerned only with proportionate amounts, namely, bole area in one plantation *compared with* that in another plantation of the same species and quality class, but worked on a different thinning grade. As the thinning grade does not materially affect the form factor of a plantation, and as our calculation can in any case be only approximate, we can omit the constant.

With these qualifications the bole area will be proportional to the quantity $n \times h \times g$, where n is the number of trees per acre, h their mean height, and g their

[1] We are deeply indebted to the Forestry Commission for supplying these figures.

[2] See, however, section 6, sub-sections (2) and (3) below.

mean breast height quarter girth. We will call this the *bole area equivalent* and designate it by the letter B. So B is an amount which is proportional to the area of cambium on the main stems of an acre of trees.

5. METHOD OF CALCULATION

As an example of the method of calculation we propose to work out a thinning schedule for Corsican pine, qu. cl. II, which is so designed that the 100 largest trees should grow at an even rate of 7·0 rings to the inch between 20 and 50 years of age. This rate of growth corresponds to an annual increment in b.h.q.g. of $\frac{1}{4}$ inch.

The first part of the calculation is shown in Table III. Column (3) shows the quarter girths of the 100 largest trees as given in the *Revised Yield Table* for qu. cl. II of this species, but smoothed so as to obviate the irregularities caused by their being recorded to the nearest $\frac{1}{4}$ inch. Column (4) is R, the number of rings per inch put on in each interval worked out in accordance with section 2 above. Columns (5), (6), (7) are the number of stems per acre, the mean height, and the mean q.g. of the main crop; they are taken from the yield table, but the quarter girths are again smoothed. B, in column (8), is the bole area equivalent and is equal to $n \times h \times g$, or col. (5) × col. (6) × col. (7). So far all the figures are derived from the yield table.

We have now to compute the numbers of trees which would be required at each thinning to allow the 100 largest trees to grow at a rate of 7 rings to the inch. This is equivalent to an increase of $\frac{1}{4}$ inch in quarter girth each year, so, starting as before from a breast height quarter girth of $5\frac{1}{4}$ inches at 20 years, column (9) can be written down. R^1, the number of rings per inch with our new thinning, is constant at 7·0. Column (11) is worked out on the principle, explained in section 4, that, on the average, the width of the annual rings produced in any thinning period will be inversely proportional to the area of cambium on an acre of plantation. R, the number of rings per inch, is inversely proportional to the ring width, so the bole area equivalent, B, which is proportional to the area of cambium, will be directly proportional to R. The new bole area equivalent, B^1, can therefore be calculated from the formula

$$\frac{B^1}{B} = \frac{R^1}{R}. \qquad \text{(I)}$$

Thus, at 20 years, $B^1 = 113{,}000 \times 7{\cdot}0/8{\cdot}1 = 98{,}000$. The other figures in column (11) are worked out in the same way.

If n^1, h^1, and g^1_m are the new number of trees, mean height, and mean quarter girth, we have the relationship

$$n^1 \times h^1 \times g^1_m = B^1. \qquad \text{(II)}$$

At 20 years, therefore, $n^1 \times h^1 \times g^1_m = 98{,}000$. The new height h^1 may be slightly different from h because there will be fewer trees per acre, but the difference will be small and, by comparing the relationship of the mean height of the crop to that of the 100 largest trees in the yield table, we can guess h^1 pretty accurately. It depends on the number of trees at each thinning and our guesses are shown in column (6) of Table IV. We thus have

$$n^1 \times g^1_m = B^1/h^1 \qquad \text{(III)}$$

TABLE III. *Corsican pine, qu. cl. II*

Age (years)	*From yield table*							*For new thinning grade*		
	100 largest trees			*Main crop*				*100 largest trees*		*Main crop*
	Mean height (feet) b_{100}	*q.g. (smoothed) (in.)* g_{100}	*Rings per inch* R	*No. of stems per acre* n	*Mean height (feet)* b_m	*q.g. (smoothed) (in.)* g_m	*Bole area equiv.* $B \div 1000$	*q.g. (in.)* g^1_{100}	*Rings per inch* R^1	*Bole area equiv.* $B^1 \div 1000$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
20	30	5·30	8·1	1,100	27½	3·75	113	5·25	7·0	98
23	35	5·95	9·2	890	32½	4·35	126	6·0	7·0	96
26	40	6·52	10·4	730	37	4·95	134	6·75	7·0	90
30	46	7·19	11·5	580	43	5·70	142	7·75	7·0	86
35	53	7·95	12·5	450	50	6·50	146	9·0	7·0	82
40	59	8·65	13·5	365	56	7·25	148	10·25	7·0	78
45	64½	9·30	14·6	305	61½	8·00	150	11·50	7·0	72
50	70	9·90		255	67	8·75	149	12·75		..

in which the right-hand side is known. To solve the equation we need only one further relationship between n^1 and g^1_m. This is provided as follows.

So long as there are more than 100 trees per acre in a plantation, the mean quarter girth (g_m) will be smaller than the mean q.g. of the 100 largest trees (which we may call the 'top quarter girth' and represent by g_{100}), and as n decreases the value of the fraction g_m/g_{100} will increase, until it reaches 1 when $n = 100$.

TABLE IV. *Corsican pine, qu. cl. II. Thinning schedule to give 7·0 rings per inch in 100 largest trees per acre*

	100 largest trees			*Main crop*				
Age (years)	*Mean bt. (feet)* b_{100}	*Mean q.g. (in.)* g^1_{100}	*Rings per inch* R^1	*Bole area equiv.* $B^1 \div 1000$	*Mean bt. (feet)* b^1	$\frac{B^1}{b^1 \times g^1_{100}}$	*No. of stems per acre* n^1	*Mean q.g. (in.)* g^1_m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
20	30	5·25		98	27½	680	930	3·8
			7·0					
23	35	6·0		96	32½	493	630	4·7
			7·0					
26	40	6·75		90	37½	356	430	5·6
			7·0					
30	46	7·75		86	43½	255	300	6·6
			7·0					
35	53	9·0		82	51	179	200	8·0
			7·0					
40	59	10·25		78	58	131	140	9·6
			7·0					
45	64½	11·50		72	64½	97	97	11·5
			7·0					
50	70	12·75		..	71	..	(70)	(13·5)

Fig. 1 shows a graph of g_m/g_{100} against n, the points on the graph being worked out from the original yield table; g_m and g_{100} are taken from columns (7) and (3) of Table III and n from column (5).

We now assume that with the new thinning grade the same relationship will hold, e.g. that when there are 300 trees per acre the value of g_m/g_{100} will be 0·850 (see Fig. 1), as it is in the yield table. This assumption may be questioned, and the limits within which it is justified are discussed later in section 6 (3). Accepting this for the present it means that, if n^1 is known, the value of g^1_m/g^1_{100} can be read off from the graph. And since g^1_{100} is known (column (9) of Table III or column (3) of Table IV) we have g^1_m.

Equation (III) can now be solved by trial and error. Firstly, a possible value of n^1 is chosen and g^1_m is calculated from equation (III). Secondly, with the same value of n^1, the value of g^1_m/g^1_{100} is read off from the graph in Fig. 1, which gives another value of g^1_m. If the two values of g^1_m are not the same, fresh values of n^1 are tried and, with a little practice, values of n^1 can be found which give the same

value of g^1_m by the two methods. Fortunately, however, the procedure can be simplified by the following device.

Direct solution for n^1. If we divide each side in equation (III) by g^1_{100} we have the relationship

$$n^1 \times \frac{g^1_m}{g^1_{100}} = \frac{B^1}{h^1 \times g^1_{100}}. \qquad \text{(IV)}$$

In this equation all the quantities on the right-hand side are known. For instance, at 20 years, B^1 is 98,000, h^1 is $27\frac{1}{2}$, and g^1_{100} is 5·25. So

$$\frac{B^1}{h^1 \times g^1_{100}} = \frac{98{,}000}{27{\cdot}5 \times 5{\cdot}25} = 680.$$

The values of this fraction at each thinning are shown in column (7) of Table IV.

Reverting to the original yield table we work out the value of $n \times g_m/g_{100}$ at

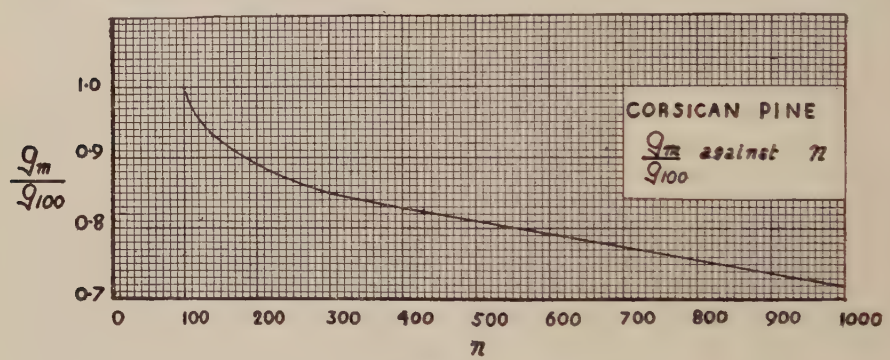

Fig. 1

each thinning from Table III and graph this value against n. The result is shown in Fig. 2. We assume, as before, that with the new thinning grade g^1_m/g^1_{100} has the same relation to n^1 as g_m/g_{100} had to n. Then $n^1 \times g^1_m/g_{100}$ will have the same relationship to n^1 as is shown in the graph.

But at each thinning

$$n^1 \times \frac{g^1_m}{g^1_{100}} = \frac{B^1}{h^1 \times g^1_{100}}$$

(equation IV) and the right-hand side is already known and has been set down in column (7) of Table IV. So we can read off n^1 from Fig. 2. Thus, at 26 years,

$$n^1 \times \frac{g^1_m}{g^1_{100}} = \frac{B^1}{h^1 \times g^1_{100}} = 356.$$

So n^1 is read off at 430. The corresponding value of g^1_m can then be worked out from equation (III). In this way the figures in columns (8) and (9) in Table V have been computed. The values at 50 years are put in by extrapolation.

6. SOURCES OF ERROR IN THE METHOD OF CALCULATION

There are no doubt many reasons for doubting the accuracy of the method of calculation which is applied in this paper. The three reasons which appear to be the most important are discussed in this section.

(1) *Use of the graph in Fig. 2.* The graph in Fig. 2 is constructed from the yield table. As all the tables for each species are constructed from a 'master yield table' for that species[1] the relationship of g_m to g_{100} to n is the same in all quality classes for any one species in the published tables. So in drawing the graph we have used

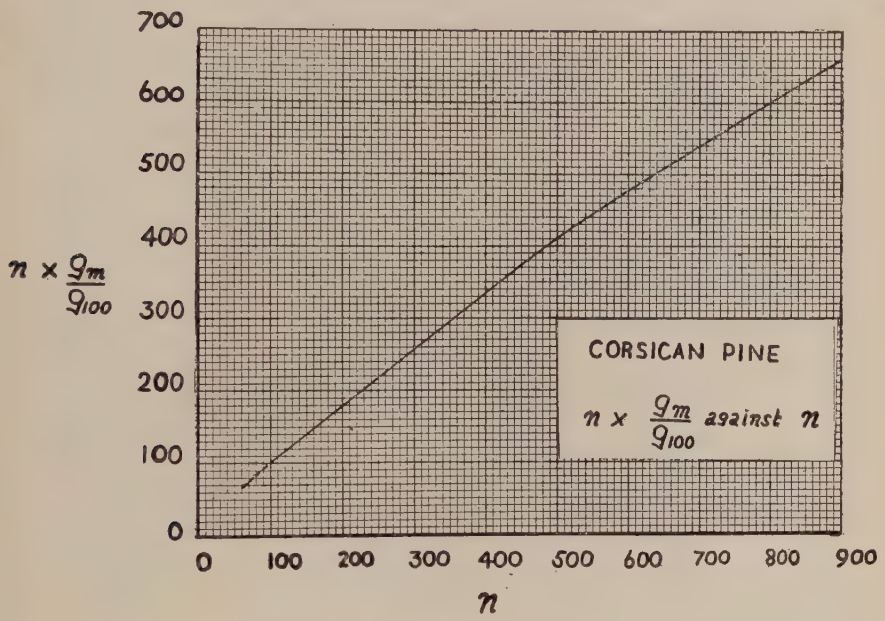

FIG. 2

the tables for all quality classes of Corsican pine and have thereby been able to insert a large number of points. For this reason it was considered wise not to smooth the quarter girths in each table—so as to remove the inaccuracy caused by their being recorded to the nearest quarter-inch—but to record the points calculated directly from the tables and to draw a smooth curve through these points. It is clear from the nature of the quantities graphed that the curve must pass through the origin, though the value of g_{100} when n is less than 100 is imaginary. Consequently, the portion of the curve which applies to values of n between 0 and 100 is shown by a broken line. Nevertheless, it is used in the calculation and, we think, appropriately.

Some doubt must arise when this graph is applied to a new grade of thinning, since we can have no guarantee that the relationship of g_m to g_{100} to n will then remain the same. The curve depends on the size distribution of the trees which are left after each thinning. If all the smaller trees are systematically removed so

[1] For the theoretical basis for this method see Hummel (7).

that those which remain are about the same size, then g_m will be nearly equal to g_{100}. If, on the other hand, many of the larger trees are removed in a thinning and some of the smallest are left, g_m will be much less than g_{100}. So the form of the graph will depend more on the kind of selection on which the thinning is based than on whether it is light or heavy.

An examination of the Bowmont plots throws some light on this subject. A graph like that in Fig. 2 has been drawn for grades C and D in the records of these

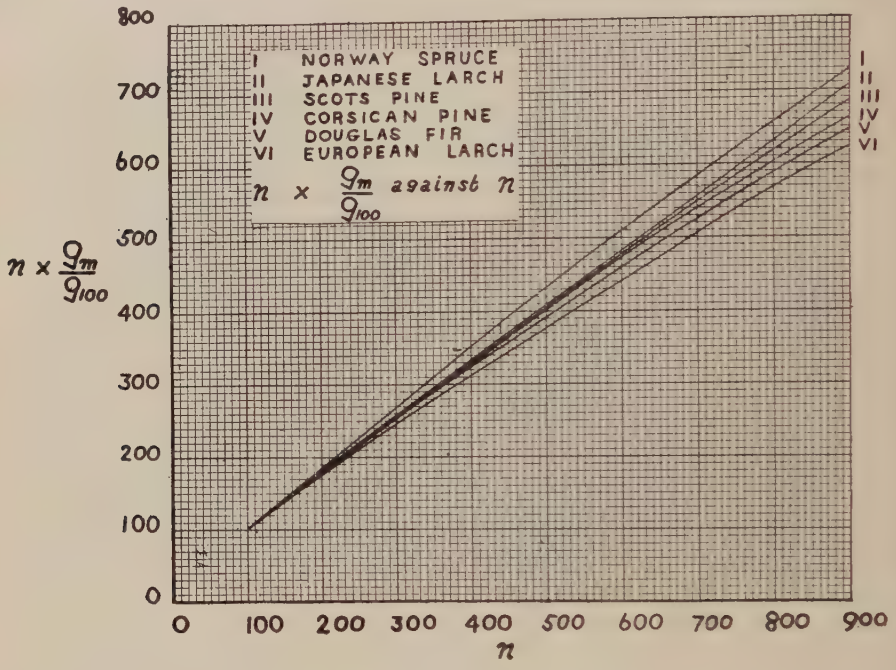

Fig. 3

plots; the two graphs appear identical, although in the C grade thinning 800 trees per acre remain at 40 years, while the D grade leaves only 272 trees.

Similar graphs have been drawn for all the other species covered by the yield tables and, as shown in Fig. 3, these all lie close together. The graph for Corsican pine happens to lie near the middle of the group and, if this curve were used for any of the other species, the error arising from this source would not be more than 10 per cent.

(2) *Ring widths and bole area.* The method of calculation is based on the principle that, if the C.A.I. is unaffected by the grade of thinning, the *average* width of the annual rings must be inversely proportional to the area of cambium, i.e. to the bole area equivalent. This principle, however, is not precisely true, as will be seen from the following simple (and exaggerated) example.

Let us suppose that all the trees in a plantation have a breast height diameter of 6 inches, and that part of the plantation is left unthinned while the other part

is thinned to half the number of trees. This second part will then have half as large a bole area per acre as the first part. Let us further suppose that in the unthinned portion the trees put on an annual ring with a width of $\frac{1}{2}$ inch. Then, according to our principle, the trees in the thinned portion should put on an annual ring with a width of 1 inch.

But the basal area increment represented by the growth of one tree which puts on a ring width of 1 inch is slightly greater than the basal area increment represented by the growth of two trees which put on an annual ring of $\frac{1}{2}$ inch. So if our principle held true the thinned portion would put on a slightly greater basal area increment than the unthinned portion; and the volume increment would also be higher. As this is contrary to our supposition we must assume that the ring width put on in the thinned portion would be slightly less than 1 inch.

TABLE V. *Annual rings per inch in the Bowmont plots. Norway spruce, qu. cl. III*

	C thinning			*D thinning*		
		Rings per inch			*Rings per inch*	
Age (years)	*No. of stems per acre*	*All trees*	*100 largest trees*	*No. of stems per acre*	*All trees*	*100 largest trees*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
20	2,417			1,942		
		20·6	11·0		15·9	8·3
25	1,840			1,017		
		19·6	11·0		9·8	8·3
30	1,507			632		
		23·6	16·5		9·2	7·9
35	1,015			387		
		16·5	11·0		7·9	7·5
40	800			272		

The error in calculation due to this cause will be small, but it may be expected that the increase in ring width which results from a heavier thinning will be somewhat less than is calculated by the method used in this paper. The error, however, is not cumulative and should tend to be self-correcting. For at the end of any thinning period the trees will have a somewhat smaller girth than is calculated, and, if the next thinning reduces the number of trees per acre to the figure shown in the table, the bole area equivalent will be lower than is calculated. This should result in the trees making broader annual rings than was anticipated during the next thinning period; and this will compensate in part for the narrower annual rings which were put on in the previous thinning period.

(3) *Ring widths on mean tree and on dominant trees.* The assumption, which has been made in section 5, that the ring width *in the 100 largest trees* is inversely proportional to the bole area per acre, is open to question and is reasonably correct only when two relatively heavy thinnings are being compared.

In a very dense plantation the smallest trees put on practically no increment and their removal hardly affects the growth of the dominant trees; but if a plantation is thinned so heavily that only the dominants and co-dominants remain, the removal of any tree is likely to enhance the growth of its neighbours. For the same reason, in a dense plantation the *average* ring width put on all the trees over a thinning period will be much less than the ring width on the dominant trees, whereas in a heavily thinned plantation the difference will be much less.

This difference is illustrated by Table V, which compares the number of rings per inch on all trees with the number of rings per inch on the 100 largest trees, firstly with a C thinning and secondly with a D thinning. The figures are calculated from the results of the Bowmont plots and show that with a heavy thinning the 'average' ring width approaches the 'dominant' ring width very closely, but that with a C thinning the difference between them is considerable.

These observations suggest that the method of computation explained in section 5 should not be applied for calculating the probable results of a heavy thinning from a yield table constructed for a light thinning. The thinnings for which the *Revised Yield Tables* are constructed are of the order C/D, i.e. they are moderately heavy, and the error arising from this cause may not be very large. Nevertheless, the influence on ring width of reducing the number of trees is likely to be less than that which is estimated, and with the new thinning grade the growth of the 100 largest trees may not be as rapid as is calculated.

7. DISCUSSION

If it were possible to design thinning grades which would produce a final crop of trees containing a desired pattern of annual ring thicknesses, the science of thinning would be greatly advanced. Present methods of thinning suffer from a lack of distinct objectives although they aim at maintaining the health and vigour of the trees and at securing reasonably clear timber. The economic aim of thinning should be to secure the best relationship between the cost of growing trees and the price which they will command when grown and, as our knowledge advances, we may hope gradually to approach this goal.

Ring widths are influenced by many other factors besides thinning. They are affected by climatic changes, by parasitic attack, and, perhaps more than is generally realized, by changes in soil condition. These other factors can be controlled only to a very limited extent, but a thinning schedule is something that can be followed, and if in a general way and under average conditions it produces the desired result this is all that we can expect from it.

It is not claimed that the method of calculating a thinning régime which is explained in this paper is free from error, but it is hoped that it will give thinning densities of the right order. The method is very simple to apply. All that is necessary is to put down a series of ring widths which it is desired to achieve in the 100 largest trees, and to construct a table like Table III. The ring pattern must be realistic, that is, it must be within the capacity of the species and the site. The next step is to work out values for $B^1/(h^1 \times g^1_{100})$ for each thinning age in the manner

explained in section 5. The numbers of trees can then be read off from the curve for the appropriate species in Fig. 3.

The accuracy of the method is dependent on the accuracy of the yield tables from which the figures are calculated; and the accuracy of a yield table consists in representing the *average* rates of growth of a large number of plantations which behave in many diverse ways. We can only control the waywardness of plantations within wide limits.

We wish to express our thanks to Mr. F. C. Hummel and Mr. J. Christie for frequent assistance and criticism during the preparation of this paper.

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APPENDIX

Formula for Number of Annual Rings per Inch put on Over a Period

(1) If in any cross-section

r = the radius o.b. g = the quarter girth o.b.
q = „ u.b. b = the bark per cent.,

then $$b = \frac{r^2-q^2}{r^2} \times 100.$$

Therefore $$q^2 = r^2\left(1-\frac{b}{100}\right),$$

and $$q = r \times \sqrt{\left(\frac{100-b}{100}\right)}$$

$$= \frac{2g}{\pi} \times \sqrt{\left(\frac{100-b}{100}\right)}. \qquad \text{(I)}$$

(2) Let R = number of rings per inch put on in a period of y years

q_1, q_2 = radius under bark at beginning and end of period
g_1, g_2 = quarter girth o.b. at beginning and end of period.

Then there are y rings in q_2-q_1 inches and there are R rings in 1 inch.

$$\text{So} \quad R = \frac{y}{q_2-q_1}. \tag{II}$$

Putting in values of q_2 and q_1 from equation (I)

$$R = \frac{y}{\frac{2}{\pi} \times \sqrt{\left(\frac{100-b}{100}\right)} \times (g_2-g_1)}$$

$$= \sqrt{\left(\frac{100}{100-b}\right)} \times \frac{\pi}{2} \times \frac{y}{g_2-g_1} \tag{III}$$

$$= \sqrt{\left(\frac{100}{100-\text{bark}\,\%}\right)} \times \frac{\pi}{2} \times \frac{\text{interval in years}}{\text{increase in quarter girth}}.$$

Applying the average bark per cent. for each species, the values of the function $\sqrt{\left(\frac{100}{100-\text{bark }\%}\right)} \times \frac{\pi}{2}$ are as follows:

Scots pine	1·70
Corsican pine	1·75
European larch	1·70
Japanese larch	1·71
Norway spruce	1·65
Sitka spruce	1·66
Douglas fir	1·65

THE PLACE OF A SPECIES IN THE FOREST, WITH SPECIAL REFERENCE TO WESTERN NORTH AMERICAN SPECIES OF CONIFER USED IN BRITAIN

By W. R. DAY

SUMMARY

The nature of the differences between the climates of the Queen Charlotte Islands and of England and Wales are discussed briefly. The author then examines the site tolerance of the principal species within their own natural range, comparing particularly the place of Sitka spruce (*Picea sitchensis* Carr.) in the forest on Graham Island with its place around Terrace and describing the Douglas fir forests of the drier eastern side of Vancouver Island and the place that Sitka spruce has in them. Factors affecting the growth of Douglas fir (*Pseudotsuga taxifolia* Brit.) are discussed. It is suggested that care is needed before it is assumed that a markedly dry summer period such as occurs in much of the Douglas fir region entails a 'dry' period as regards supply to the tree. Illustrations are given from eastern North America of changes in type of site occupied by a species with change in climatic or edaphic environment. Observation of the relative position of a species in the forest as climate changes makes it possible to suggest the place of Sitka spruce and Douglas fir in Great Britain.

ECONOMIC forestry in Europe has been and still is based mainly on the exploitation of indigenous species growing in semi-natural forests; that is in forests which are composed of species which would occur naturally on the site, though not necessarily in the proportions, or in the manner, determined by the necessities of economic management. This has relieved management, to a considerable extent, of the need to consider whether a species is adequately suited to its situation. The chance of an environmental misfit has only arisen to any marked extent when there has been a transference from one forest zone to another as, for example, with the planting of European larch (*Larix decidua* Mill.) or Norway spruce (*Picea abies* Karst.) in the oak–beech forest zone or when, with a widely distributed species such as the common pine (*Pinus silvestris* L.), a strain native to one part of its range is moved to another part with an appreciably different climate.

The position is rather different when the use of species native to another continent is considered. Thus the species of conifer native to western North America, which are used economically in western Europe, occur naturally over a similar latitudinal range to that within which they are used as exotics; but although the climates of the two seaboards are in many ways similar, there is no denying that appreciable differences exist between them. It is accordingly fundamentally necessary to appreciate what the nature of such differences is, if an efficient use of these species is to be made. An example is provided by a comparison between the Queen Charlotte Islands and England and Wales. The species of forest importance concerned are western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western red cedar (*Thuja plicata* Donn.), and especially Sitka spruce (*Picea sitchensis* (Bong.) Carr.), which, in Britain, has been used so widely in afforestations. These two regions occupy the same latitudes. The mean monthly temperature for Masset, a coastal place in the latitude of Carlisle, is almost exactly similar to that for Buxton, in Derbyshire, at an elevation of 1,000 feet above sea-level, and it is practically the

same as that for Aberdeen, also a coastal town, but situated three degrees of latitude farther north. Latitude for latitude, thus, the Queen Charlotte Islands have a cooler climate than England and Wales. There are also differences with regard to the distribution of precipitation. The annual period of lower precipitation begins in June and continues to the end of August, on the average; whereas in many parts of England and Wales it begins in late winter and ends in June. The tendency for the gain in soil moisture in the spring to fall below the loss by transpiration and evaporation is, thus, probably much greater in England and Wales, and on some soils this could be an important characteristic.

The climate of the Queen Charlotte Islands is also not only cooler but also more humid. The strongest evidence for this relatively great humidity is to be seen in the very great development of mosses, not only on the ground, but also on the branches of trees, even to considerable heights. Their bright yellow-brown provides one of the principal colour contrasts in the forests. Its effect is often added to by the development of long hanging lichens (*Usnea* spp.) on branches. This very great development of moss and sometimes of lichen is very striking to the visitor from England and Wales, to whom it is quite strange and is not typical of the forests of his own country. The coolness of the climate is shown further in the heavy snowfall on mountains which are no higher than those which occur in England and Wales: moreover the snow lasts throughout the year to a much greater extent than anywhere in Britain. Thus whereas in Scotland, in the Highlands, several hundred miles farther north, snow remaining from the previous winter can be found in late August only in very few places, it is quite obvious at any place where there is a view of the western mountains in the Queen Charlotte Islands, as for example, from the village of Queen Charlotte City in the south of Graham Island.

England and Wales has, thus, a warmer and less humid climate, even with equivalent amounts of annual precipitation: and in addition its period of low precipitation begins earlier in the year, in late winter in most places, and not in midsummer: further, the period of low precipitation is on the average of greater duration. The estimation of the effect of climatic differences such as these on the resultant supply of the needs of the tree constitutes one of the most difficult problems to be faced in the cultivation of the western North American species as exotics. It is unlikely that a perfect climatic fit will be made in the new environment; still less that the complex general environment, with its living as well as non-living factors, will be perfect from the standpoint of the growth of the introduced species. It is simply the problem of trying to arrange things so that growth is obtained which is satisfactory economically, and plainly, the better for the species in question is the fit of the climatic aspect of the new environment, the more likely will it be possible to do this.

THE EFFICIENCY OF FIT OF A SPECIES WITHIN ITS ENVIRONMENTAL RANGE

A. *Sitka spruce in Graham Island and around Terrace*

Some light on this problem is obtained if the general site tolerance of a species in different parts of its natural environmental range is considered, and this is

especially true in the case of widely distributed species. The site tolerance of a species is determined partly by ability to regenerate and partly by ability to maintain reasonably healthy growth subsequently in competition with its associates. This may be illustrated by reference to Sitka spruce and its associated species in the limited parts of its native range in which the writer has been able to make observations.

The central part of Graham Island is hilly country in which the higher peaks rise to a maximum of about 2,500 feet above sea-level. Except where fellings have taken place, the whole is covered with old-growth mixed forest which consists, at the lower elevations, of western hemlock, western red cedar, and Sitka spruce, with red alder (*Alnus rubra* Bong.) as the only large broadleaved tree: lodge pole pine (*Pinus contorta* Dougl.[1]) occurs only in swamps and on their edges in this part of the country. The proportionate specific composition of the forest is partly determined by the manner in which regeneration took place, as for example after some catastrophe such as fire or wind-throw and the time which has elapsed since this catastrophe took place; or in which regeneration is now taking place in the ordinary non-catastrophic development of the forest which perhaps, though in reality not entirely correctly, is considered usually to be its truly natural state. If, however, the cyclical development of the forest in composition, within the limits of the species which comprise the local forest association, is set aside and the forest is considered in that state in which its complex canopy, with all its storeys, is more or less fully developed, then it can be seen that the proportionate specific composition tends largely to be related to topographical position as determining loss or receipt of water and the associated soluble nutrients and also, in part, depth and character of soil owing to the natural processes of erosion. Without going into detail it may be said that it is possible for all the three principal species of conifer to occur in all situations with the exception of the more infertile sites in swamps; but that the character of the local drainage conditions taken in conjunction with the character downwards of the soil profile occupied by the roots mainly determines the relative position of dominance which any of them occupy. The range of site over which a species forms part of the dominating storeys in the complex canopy may be taken as a measure of its site tolerance: the position with regard to this in central Graham Island may be summarized, shortly, as follows:

1. Markedly water-losing sites such as tops of knolls, with a clearly podsolized soil, which is shallow, well drained, and overlies hard rock. Western red cedar is the principal dominant with some and usually poorer western hemlock. Sitka spruce may regenerate, but appears to be suppressed when of no great age. If the soil is immature and has no marked covering of raw humus, in which case it may resemble a European brown forest soil, Sitka spruce may also be among the dominants.

2. Water-losing sites such as rounded hill-tops or convex slopes. The soil is typically a brown podsol with a narrow but usually clearly defined leached layer and on the average is moderately shallow: it overlies either compacted till with

[1] Used here to cover all types without differentiation into its various forms.

impeded drainage, or hard rock. Western hemlock is the principal dominant, but good western red cedar occur and usually a few large Sitka spruce stand up as emergents. The main species in regeneration as the high canopy thins is hemlock; but if the soil surface is disturbed, as by wind-throw or fire, the proportion of spruce seedlings rises appreciably.

3. Water-receiving sites but with well-drained upper soil layers. The soil may be a brown podsol; or it may approach a brown earth with humus of a mull type. Sitka spruce tends to be the chief dominant; but large hemlock and cedar also occur. These sites, which include the lower valley slopes and the better drained alluvial soils, carry the larger trees and, if well stocked, the greater volumes in standing timber.

4. Water-receiving sites with marked impedance in drainage. They are often more or less, or may actually be, swampy. The soils are gleys, sometimes with a covering of peat; water is often near the surface and may sometimes run over it in the wetter parts. Western red cedar is markedly the dominant species and if of any age always has a dead top. Sitka spruce usually occurs but rather sparsely; it is often as tall as the cedar. Western hemlock is the most abundant species but tends to be not more than co-dominant and on the wetter sites is usually sub-dominant.

It should be noted that in this short summary swamp or muskeg types, shallow gleyed podsols, and peat podsols have been excluded and that actually any chosen area is much more complex than this simple analysis might lead one to expect. Lodge pole pine is not seen except in or near muskeg. Red alder often occurs in open places in types 3 and 4 especially: it is, however, characteristically abundant, on these types, in regeneration after the forest has been destroyed: i.e. it is typically an early occurring species in the secondary forest succession. Western red cedar appears as the most site tolerant of the three principal species; western hemlock follows it closely in tolerance, while Sitka spruce is nearly always the most site sensitive and, as observation in the forest shows clearly, proportionately the most affected in growth vigour by any trend towards infertility. The most site-tolerant conifer is probably lodge pole pine; but in this part of the country it is only able to compete satisfactorily for a dominant position in the canopy in mature forest in very inferior situations such as shallowly rooted peat podsols and in the less wet parts of sphagnum swamps.

This distribution of species as dominants in forest with a maturely developed complex canopy may be contrasted with that which occurs in the vicinity of Terrace, in much the same latitude and on the edge of the eastern distribution of Sitka spruce. This region has a hotter summer and a colder winter than occurs at equivalent elevations in Graham Island. The annual period of lower precipitation begins in April and continues until the end of August. Mosses and lichens are much less abundant on trees, and the indications are that the climate is less humid. This is an alpine region with mountains rising up to about 6,500 feet above sea-level. The main valley, that of the Skeena River, however, runs east and west, giving entry for westerly winds from the sea.

The forest round Terrace is of more complex specific composition than that which occurs in the Queen Charlotte Islands. The main species which occur, in addition to those already mentioned, are paper birch (*Betula papyrifera* Marsh.), black cottonwood (*Populus trichocarpa* Hook.), aspen (*Populus tremuloides* Michx.), and Pacific silver fir (*Abies amabilis* (Lind.) Forbes). One of the principal differences in the forest is the tendency for lodge pole pine to dominate at first in second-growth areas regenerated after fire: in the Queen Charlotte Islands this may happen, but usually does not although this pine is present. This dominance of pine after fire is to be regarded as an indication of more difficult soil surface conditions for regeneration, these conditions being produced by the warmer growing season with its less humid atmosphere. Under these new conditions Sitka spruce is typically, in mature forest, a tree of moist water-receiving sites. Its ability to become established on most well-drained places providing the soil surface favours its regeneration, which is typical of the forest in the maritime cool humid climate of the Queen Charlotte Islands, is no longer maintained. The situation on the lower slopes and in the valleys may now be summarized very roughly:

1. Water-losing sites with a shallow soil and well-drained stony subsoil or overlying hard rock; or flattish sites with a soil which consists largely of coarse round hard cobblestones and is very freely draining. Dominant species lodge pole pine and western hemlock usually with some western red cedar. This is poor forest which, on the drier sites, tends to be open. A low, poor canopy of hemlock with some cedar may form the final dominant canopy, especially as there is some improvement in fertility. Sitka spruce may then occur sparsely, but it does not attain any size and only survives because of the poor condition of the high canopy.

2. Well-drained and typically water-losing sites on slopes, or well-drained sandy loams or loamy sands on flatter areas. The mature soil is typically a brown podsol, but fully developed podsols occur. The principal dominants in mature forest are western hemlock and amabilis fir. Western red cedar often occurs relatively abundantly. Sitka spruce usually occurs to some extent as the sites become increasingly moist. Amabilis fir may be absent, especially if the forest represents the result of a first regeneration after fire.

3. Well-drained (topographically) but water-receiving sites; flattish areas with a heavy soil, or if with a lighter soil, not excessively drained and with a water-table. The soils are variable according to situation and history; brown podsols, immature alluvial soils, and gleys are represented. These sites bear the finer parts of the forest. Sitka spruce is a characteristic dominant and ordinarily occupies the position of emergent in the canopy. Western red cedar is common and may make a very fine tree. Western hemlock also grows to large size: it is always present on the more mature soils, but may be absent on the immature alluvial soils. Black cottonwood is usually represented on the gleys and immature soils: on the latter, by river sides, it may be the principal dominant; it always represents an early stage in the successional development of the forest as this is theoretically considered in relation to the development of a climax. Amabilis fir often occurs in this type of forest but, as seen, is rarely of importance.

4. Water-receiving and usually rather flat sites with a shallow depth of well-drained soil and wet subsoils; or gleys consisting of a reticulation of slight rises with wet swampy hollows; or similar reticulations consisting of peat with the higher parts well drained and the lower parts swampy. These sites are characteristically situated on the less well-drained places beside lakes and rivers. Skunk cabbage (*Lysichiton camtschatcense*) is characteristic of the wetter places; tall shield ferns and woody *Rubus* species, usually with some skunk cabbage, of the rather drier but still very moist parts. Western red cedar is usually the principal dominant. Sitka spruce always occurs, but usually as a rather sparsely scattered tree; it usually equals the cedar in height and may be a distinct emergent from the canopy. Western hemlock is abundant but remains apparently subdominant; it is possible that some of the hemlock in these swampy places are mountain hemlock (*Tsuga mertensiana* (Bong.) Sarg.). When swampy, this is an open type of forest; alders then always occur and broadleaved shrubs are usually abundant.

5. Water-receiving flat sites characterized by an abundance of *Sphagnum* and essentially similar to much of the muskeg in Graham Island. This is very poorly represented, apparently. A small area seen carried rather poor lodge pole pine, western red cedar, and a few Sitka spruce. As in the case of much of the Graham Island muskeg, this was essentially a peat moss which carried scattered trees.

It has to be remembered again that the above is a crude and very general classification and is not intended to do more than give a brief view of limited parts of a widespread and complex forested country.

The main differences in the forest between Graham Island and the Terrace region may be summarized as follows: around Terrace

(*a*) the winter is colder and the growing season warmer,
(*b*) the relatively dry summer period is longer,
(*c*) the indications are that atmospheric humidity during the growing season is lower,

than in Graham Island. The consequence of this is seen in the distribution of a relatively site-sensitive species such as Sitka spruce. If one specifies a soil of reasonably good quality such as a well-drained loam, it is possible in Graham Island for Sitka spruce to occur as a prominent element in the forest in any situation, even, for example, on the top of a steeply sloping knoll with a shallow soil; but around Terrace on the lower slopes of the mountains and in the valleys this would not be; western hemlock probably with amabilis fir and some western red cedar would constitute the forest, or if the situation was markedly water-losing and with a poor type of subsoil, such as hard rock, the forest might consist of lodge pole pine with western hemlock and very poor cedar.

An analysis for the more site-tolerant species shows similar tendencies. The well-drained sites in Graham Island on which lodge pole pine is able to survive as a dominant seem to be chiefly the more elluviated soils derived from the coastal sands; elsewhere western red cedar appears as the principal dominant on the well-drained poorer sites, followed closely by western hemlock. Western hemlock is, however, the main dominant of poor, dry sites around Terrace, characterized by

lichens, together with lodge pole pine; such cedar as occur are of inferior growth to these. It would appear thus that western red cedar is favoured by the more humid climate of Graham Island to a greater extent than is western hemlock or lodge pole pine; that is, that its tolerance of well-drained 'dry' sites depends on a relatively high degree of atmospheric humidity during the growing season to a greater extent than with those species. This is supported by its position of dominance in respect to western hemlock, in *Lysichiton–Rubus*–fern types: the wetness of these apparently compensates for the climatic adversity, so far as cedar is concerned, and hemlock takes a subdominant position. Lodge pole pine has not been observed in these relatively fertile swamp types.

TABLE I. *Order of site tolerance, beginning with the more adaptable species, and applying to sites of low quality*

Site conditions	Freely drained, leached soils with raw humus. Water-losing site		Impeded drainage (swamp or muskeg types). Shallow rooting; wet subsoil. Water-receiving, or retaining site	
Region	*Graham Island*	*Terrace*	*Graham Island*	*Terrace*
Field layer type under standing forest	*Moss–Herb*	*Moss–Lichen*	‡*Gaultheria–Ledum Sphagnum*	§*Lysichiton–Rubus–Athyrium*
	*Thuja plicata**	*Pinus contorta*	*Pinus contorta*	*Thuja plicata*
	Tsuga heterophylla	*Tsuga heterophylla*	*Thuja plicata*	*Picea sitchensis*
	Picea sitchensis	*Thuja plicata*	*Picea sitchensis*	*Tsuga heterophylla* (possibly with *Ts. mertensiana*)
		Picea sitchensis†		

* Except on coastal sands usually with impeded drainage, on which *P. sitchensis* and *P. contorta* dominate (*Gaultheria* type).

† Usually absent.

‡ Unusual round Terrace, where *P. sitchensis* may show greater tolerance.

§ Not examined in Graham Island, where the order of species is probably similar.

On the basis of observations such as these it is possible to draw up orders for site tolerance such as those given in Table I. These refer only to the poorer and limiting situations. It will be seen that on the whole Sitka spruce comes out as the most site-sensitive species. It should be remembered that mature forest with a fully developed complex canopy is referred to. There are situations in which this position for Sitka spruce appears to be contradicted, as for example when it is acting as a pioneer species in the colonization of recently deposited coastal sand; but it is believed that a full analysis of these would only support the conclusion indicated in the table.

B. *Douglas fir and Sitka spruce in eastern Vancouver Island*

This analysis of the site tolerance of Sitka spruce relative to its associated species as these occur between latitudes 53° and 54° N. is supported by observations in Vancouver Island, where Douglas fir (*Pseudotsuga taxifolia* (Lam.) Brit.), together

with other species, enters into the composition of the forest. Douglas fir[1] is the most abundant species on the eastern and drier side of Vancouver Island. It occurs in a wide variety of situations, and into these it is not proposed to attempt to enter in any detailed way. Roughly and very generally, several types of situation may be recognized according to the type of vegetation which they bear. The remarks which follow apply to situations between latitudes 47° and 49° N.

The more fertile sites may be characterized as moist fern–herb sites. They occupy the more water-receiving situations, but are not ill drained, at least not in the upper soil layers. Typical plants are:

Ferns: *Polystichum munitum*; *Athyrium felix-femina*; *Blechnum spicant*; *Adiantum pedatum.*

Herbs: *Achlys triphylla*; *Tiarella trifoliata*; *Urtica lyalli*; *Claytonia* spp.; and many other plants.

Shrubs: *Fatsia horrida*; *Rubus spectabilis* and other *Rubus* spp.; *Symphoricarpus.*

Not all of the species mentioned necessarily occur together, e.g. *Adiantum pedatum*, the maidenhair fern, is characteristic of sites considered to be of a more fertile type than those occupied by *P. munitum*, the sword fern, and seems rarely if ever to occur mixed with it. If the forest is fully developed there is a complex canopy consisting of several storeys: e.g. by Cameron Creek in Macmillan Park one finds:

A. Douglas fir emergents of about 250 feet in height; very large trees, the tops of many of which are now broken.
B. A co-dominant canopy of western red cedar, western hemlock, and an occasional grand fir (*Abies grandis* Lind.).
C. Western hemlock, western red cedar, and *Acer macrophyllum* as subdominants.
D. Western hemlock and western red cedar as understory trees.
E. Scattered small hemlock and cedar.
F. The ground vegetation (*P. munitum*, *Achlys triphylla*, *Tiarella trifoliata*, with *Adiantum* abundant locally in moist places).

The trees in strata A, B, and C are tall by European standards and the most dense story of the canopy is that formed by the co-dominants. Such forest represents a late stage in successional development.

This moist fern–herb group of sites grades, with variation, into other types which, on the average, have a lower site index height quality class. A moss type is thus recognized as occupying an intermediate position and in which the soil surface, as seen under pure second-growth Douglas fir in high canopy, is principally moss covered. Such sites are rarely entirely consistent and in the more moist but still well-drained places a little *P. munitum* may be seen or *A. triphylla*, indicating an approach to a fern–herb type, and in others, perhaps, some *Gaultheria shallon*, the

[1] In this discussion no attempt is made to distinguish between the different types of Douglas fir (Peace (6)), but coastal forms are usually referred to.

ericaceous shrub known as salal, which may attain a height of about 7 feet but is often much shorter. *G. shallon* indicates, if dominant, a still poorer type; as is so often the case, the plants which accompany it are of importance as indicators of site fertility. If *P. munitum* occurs fertility may be above the average ordinarily observed for salal sites; if *Arctostaphyllos uva-ursi* occurs frequently, it may be rather below the average and this will be especially indicated if lichens occur on the soil surface. One of the poorer sites is characterized by *A. uva-ursi* and lichens. The site index of Douglas fir drops as the indications for fertility become poorer, but to some extent the tendency for it to maintain a dominant canopy and to keep the more shade-tolerant hemlock and cedar subdominant or suppressed increases and the structure of the complex canopy becomes simplified. Eventually pines may hold a place in the canopy for long periods. Thus on gravelly soil on a site situated on a plateau there was

A. A dominant canopy of Douglas fir, with some western white pine and an occasional lodge pole pine.
B. A little western red cedar and western hemlock as understory trees.
C. A ground vegetation characterized by poor, short *G. shallon*, *Pteridium aquilinum*, and *Vaccinium californicum*: in a cleared and regenerating area, lichens were common between the shrubs of *Vaccinium* and some *A. uva-ursi* occurred; lodge pole pine was the principal tree species regenerating.

The dominant Douglas fir on this site, although only about 80 to 100 feet in height, showed scraggy open, rather flat-topped crowns which are typical often of trees the growth of which is being severely restricted by site conditions.

Sitka spruce comes into this sequence as capable of growing, though not necessarily of surviving in competition, on moist fern–herb types: e.g. in the western side of the Olympic Peninsula, in Washington, both Sitka spruce and Douglas fir may be seen growing to large size on such sites: this is a humid region of high rainfall. Examples occur also on the fan of Qualicum Creek, on the east coast and within one of the climatically drier areas. There is also a case at Cowichan Lake, in 40-year-old second-growth Douglas fir forest, in which Sitka spruce has regenerated to some extent under red alder which grows on a flush site characterized by tall *P. munitum*, *Equisetum*, *Lysichiton camtschatcense*, and various luxuriantly growing herbs. Such examples as the latter make it obvious that the presence of an abundant supply of available water of good nutrient status enables Sitka spruce to grow successfully in this drier side of Vancouver Island; though it would probably never make so fine a tree as in more humid regions of higher rainfall.

C. *Factors affecting the growth of Douglas fir*

The series of edaphic situations which have been very roughly indicated above by means of some of the plants typical of the ground flora represent a regression from relatively high availability of water per unit volume of soil to relatively low availability; from active nitrification in the soil surface to poor nitrification; from a higher nutrient status per unit volume to a lower nutrient status; from a soil

structure relatively favourable to feeding root development to one less favourable, and so on. All these things help, plainly, to control the rate of growth of the trees and so to determine the value of the site index as measured by height growth at a particular age. Among these things perhaps availability of water holds a place of particular importance, if only because of the interpretation which is usually placed on the various site characteristics.

Gaultheria–lichen or *Arctostaphyllos*–lichen sites are sometimes referred to as dry sites and Douglas fir is thought of as a tree which is able to occupy dry soils. The word 'dry' in this case must necessarily mean lacking in water, considering the demand made by the tree. Is it really true that these poorer and drier sites are markedly deficient in supply of available water and so 'dry'?

The important aspect of growth raised by this question relates to the relationship between the supply characteristic for a particular site and the demand of the trees which grow on it. There are at least two aspects to this problem. Thus Sitka spruce will grow satisfactorily in competition with its associated species on freely drained water-losing sites in the cool humid climate of Graham Island; it tends not to be able to do this around Terrace where the growing season is warmer and rather drier and gives way to western hemlock, western red cedar, and amabilis fir; in the drier parts, in the eastern side of Vancouver Island, with a still warmer and drier summer period, it only survives when the conditions of water-supply are particularly good and never occurs in well-drained water-losing sites. There is thus, on the one side, the question of specific character: Douglas fir and Sitka spruce attain their greater development on sites of very similar character; but plainly the one species is able to endure a dry warm growing season much better than the other. The other aspect of this question is concerned with endurance of actual deficiency in water-supply in the soil: what evidence is there that in its native forests, in which it attains a considerable age as a characteristic dominant, such endurance is ever frequently demanded of Douglas fir?

The work of Gessel and Lloyd (5) is of interest in regard to this matter. It was concerned with the effect of physical soil properties on Douglas fir site quality in north-western Washington. The sites worked on showed variations in soil texture from coarse to medium, but excluded clays. It is shown that the site index (mean height of dominants and co-dominants at 100 years) increases with change in soil texture from coarse to medium and with rise in annual precipitation from 25 to 40 inches, on soils in which there is no restriction in rooting depth owing to pan formation, or other consolidation in the subsoil. Soils with pan formation and mostly of medium texture showed a similar increase in site index with increase in annual precipitation. A rise above 40 inches, however, is accompanied by very little rise, or even a decrease in site index value. Much the greater part of the annual precipitation in this region occurs between September and May and the authors say that 'they have frequently been amazed to find the litter and surface soil entirely dry under a Douglas-fir canopy following rather heavy rains. In view of this, the conclusion seems justified that Douglas-fir growing in this region must, for the most part, depend on soil moisture stored in the soil profile at the beginning of the growing season.'

The dependence of Douglas fir, probably in most situations in which it grows naturally, on water stored in the soil for its supply during the summer needs especially to be noted. The very fact that over wide areas this species produces satisfactory forest means that this water-supply is adequate, taken as a whole, in spite of a climate with a low summer rainfall. No critical shortage of water is, in fact, endured, taking the forest as a whole, and the necessary corollary is that in such areas, in which its growth is successful over long periods, the volume of rootable soil usually is adequate to hold the necessary supply of water: in fact the occurrence of a long dry summer period, in many of the places in which this species grows naturally, does not mean that there is, in general, any critical water shortage during much of the life of the forest. An adequate natural thinning owing to competition is assumed here.

There is indirect evidence that Douglas fir occupies sites in which water-supply is adequate, at least for long periods of its development: and alternatively that if such a state of inadequate supply eventually develops, the tree begins to fail. Thus Boyce and Wagg (1), in discussing the development of conk rot caused by *Fomes* (*Trametes*) *pini* in old-growth forests in Oregon (*c.* latitude 44° N.), state that a low incidence of rot is associated with the presence of western red cedar and western hemlock with Douglas fir. These species, however, 'prefer the flatter areas on benches, lower slopes and bottom lands'; that is to say, they prefer the more water-receiving and relatively high nutrient status sites and it is on these that Douglas fir tends to be relatively free from conk rot. Incense cedar (*Libocedrus decurrens* Torr.) is an indication of the probable presence of a high degree of conk rot; but this species is associated with 'the drier, warmer upper slopes and hog backs'; that is with the more water and nutrient losing sites. There are indications that the onset of serious stem and crown rot is associated with, amongst other things, failure in soil supply to meet the demands of the trees and, while this can happen comparatively early in a valley, for example on moist fern–herb sites in which the soil is good in quality per unit volume but deficient in regard to rooting space, it is more likely to happen generally on warm upper slopes and ridges which naturally are water-losing situations and subject to the normal soil-losing processes of erosion.

Another indication that, in Vancouver Island at least, Douglas fir is not short of water during the dry summer period is to be found in the well-developed, broad, late wood which it seems fairly consistently to produce, even on relatively poor sites, in terms of site index, on the eastern side of the island. Chalk's (2) observations suggest strongly that such late wood is not formed in the absence of adequate water-supply, and those of Day (4) on the absence of well-developed late wood in Sitka spruce and other species, in Britain, on sites on which drought crack occurred, point in the same direction. There seems in fact never to have been any demonstration of an association between inadequate soil water-supply and the formation of well-developed late wood, but it is believed that many indications to the contrary could be found.

One is concerned here with the question of assessing the causes of slow growth. This is a complex and difficult question. It is necessary to distinguish between at

least two general situations. In the one case the rate of growth is at first fast but after a short period, say from 15 to 30 or 40 years, becomes unduly slow. This is the case in which soil supply is abundantly present for a small tree but unduly restricted for a large one. The other case is that in which, even though a tree may be a dominant and its crown not unduly restricted, its growth is still slow. This seems clearly to be a case of restriction in growth rate by a general limitation in rate of uptake of supplies from the soil, and in resolving it one is concerned with the causes of this. Plainly the mere water-holding capacity of the soil may be only one of these and not necessarily the most important. Slowly grown Douglas fir of considerable age, which for long periods, on sites of relatively low index value, that is of low fertility in terms of growth rate, have produced fairly narrow ringed wood with well-developed late wood consistently for long periods of time, seem to fit in here. It would appear that the problem is not one of limitation in uptake of supply, all the apparatus in the form of a well-developed root system being present to take up more if it were available; this is the situation which arises when, for example, drought crack develops (Day (4)): it is much more one concerned with restriction in development of the absorbing apparatus in such a way that the amount available to the tree is always kept below what potentially it could use. This is essentially the 'Japanese garden' method of restricting growth rate and is determined by such things as soil texture, consolidation, and stoniness; in fact with the physical factors which so largely determine the intensity, per unit volume of rooted soil, of development of feeding roots and the rate of supply to them. It would appear that it is this restriction in rate of absorption which the more site-tolerant species are able to endure with comparative satisfaction; or alternatively which they are able to overcome to some extent by manner of root extension.

ILLUSTRATIONS FROM EASTERN NORTH AMERICA OF CHANGE IN TYPE OF SITE OCCUPIED BY A SPECIES, WITH CHANGE IN CLIMATIC OR EDAPHIC ENVIRONMENT

The tendency for Sitka spruce to become increasingly confined, as a successful dominant, to the more moist situations, as the growing season within its native range becomes warmer and drier, is paralleled with species which are characteristic of the forest in north-eastern America. The more northerly or boreal forest has amongst its characteristic dominants, on well-drained soils, black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*P. glauca* (Meonch.) Voss), silver fir (*Abies balsamea* (L.) Mill), and tamarack (*Larix laricina* (DuRoi) Koch): in the somewhat similar Acadian forest red spruce (*P. rubens* Sarg.) also occurs as such a dominant; but the tamarack only in swamps, or as a pioneer species on temporarily cleared land. The northern and upland part of New Hampshire is characterized by forest in which spruces and balsam fir occur as part of the typical climax forest. The southern part of the State, which in parts is less elevated, is characterized largely by the northern mixed hardwood–hemlock forest of which the hard (*Acer saccharum* Marsh) and red (*A. rubrum* L.) maples, the American beech (*Fagus grandifolia* Ehrh.), the eastern hemlock (*Tsuga canadensis* (L.) Carr.), and eastern white pine (*Pinus strobus* L.) are characteristic species. Corn (*Zea mays*) may be grown as a

field crop within the mixed hardwood–hemlock forest zone; but the upland northern part of the State has a climate with a too cool, short, growing season to ripen corn cobs. Black spruce and to some extent red spruce and balsam fir, which are characteristic dominants in the north, occur in mixed hardwood–hemlock forest only in swamps as enduring dominants; this is true also of the tamarack: red spruce may regenerate and grow for a time on well-drained soils, but it is always suppressed and killed by the shade-tolerant dominants. The tamarack, which is an efficient colonizer of abandoned fields in the northern uplands, together with other species such as white spruce and paper birch, is unable to colonize such places in the mixed hardwood–hemlock forest, white and to some extent red pine (*P. resinosa* Sol.) taking its place. It may be seen, however, growing on well-drained soils as a planted tree; but it does not regenerate on them and is confined to swamps as a naturally occurring dominant.

It may thus be taken that there is a general tendency for a species to be confined to the more moist situations as its range extends into regions which are hotter and drier than its optimum. The fairly general association of spruces with moist sites in Britain, in the minds of foresters, is an example of a rough rule learned by the demonstration of this in practice; for a great deal of Britain, and especially the eastern and southern parts, is in the oak–beech forest zone and is not suited climatically to the long continued growth of spruces as dominants.

The tendency for Douglas fir increasingly to remain dominant as, within limits, the site becomes increasingly dry, in the sense that the situation becomes increasingly water-losing, is paralleled to some extent by *P. strobus*. In New England this species attains its best development on moist water-receiving but adequately drained sites. There it is a long-lived tree, standing as an emergent above the main canopy composed of more shade-tolerant species. It is on these sites that the complex canopy of the forest shows its finest development. On water-losing and drier, but not markedly dry sites, on which it may have regenerated *en masse*, as after a fire, or on an abandoned field, its canopy will remain dominant for long periods and prevent the development of any appreciable understory of shade-tolerant species; though given lack of disturbance, these will eventually form the forest. In still inferior situations, as for example on rocky well-drained places or the more coarse and freely draining soils, it seems to form one of the permanent dominants. The more shade-tolerant species tend to fail early on such sites and to be unable to prevent its regeneration. A similar distribution of eastern white pine is markedly to be observed in flying over the 'boreal edge' forest of southern Ontario—a forest closely related in type to the northern hardwood–hemlock forest of New England.

INDICATIONS FOR THE PLACE OF SITKA SPRUCE AND DOUGLAS FIR IN BRITAIN

Such trends in species distribution and dominance are, of course, well recognized and appropriate examples can easily be quoted from Europe, e.g. Norway spruce and European larch, including with it the northern Siberian larch, are both lowland species in the more northerly latitudes of their range, but essentially upland species in the more southerly. This distributional change is undoubtedly

related to change in climate. The work of Penman (7) illustrates some aspects of this. He shows that Britain may be zoned regionally according to whether there is an excess, or deficiency, of percolation of water into the soil when compared with the loss by evaporation and transpiration. The drier part of Britain, as measured in this way, constitutes the area which naturally is the oak–beech forest zone and in which, accordingly, shade-tolerant conifers which are characteristic of the cooler northern, or montane, coniferous forest may be expected to be at a disadvantage, unless special soil conditions help to counteract the climate characteristics of the environment. Of the two species of western American conifer principally discussed here, Sitka spruce is more nearly suited to the zone of the moist northern, or montane, coniferous forest in western Europe and Douglas fir to that occupied by oak–beech forest. Species such as western hemlock and western red cedar probably occupy an intermediate position. These are, of course, summarized statements and need to be interpreted in light of the internal variation of these species.

It would be rash to assume that there is any exact agreement with regard to these things, and still more rash to forget the very important part which soil conditions play in determining the length of life over which a species of tree will remain healthy (Day (3)). Experience with Norway and Sitka spruce should not be forgotten in this respect: either species may succeed where the other may fail, and there is very strong evidence that this differential success of the two species is being demonstrated at the present time in Britain. It is also necessary to remember that a species which is unsuited to a particular climatic, or edaphic, situation may yet grow sufficiently well as a short-lived crop to make its cultivation worth while under particular circumstances; though probably at considerably increased risk. In terms of general position as dominants in permanent forest, however, it would seem to be clear that in Britain Sitka spruce becomes increasingly of general use, irrespective of edaphic situation, as the climate becomes cooler and more humid. Alternatively it will need increasingly favourable soil conditions for long continued healthy growth, as the climate becomes increasingly warm and less humid; this means that it will then become increasingly a less useful tree generally and will tend only to be suited to specially favourable situations.

Douglas fir, on the other hand, may be expected to be favoured by increases in temperature; it will, however, need an adequate soil supply if its growth is to continue satisfactory for any length of time, and in many situations in the warmer part of Britain this will be found to constitute a critical point. There are already indications of the breakdown of this species on fertile but shallow soils in parts of England in which there is an appreciable excess of water lost from the soil by evaporation and transpiration as compared with that gained by percolation during the growing season. It is probable, thus, that for reasons such as this the better types of Douglas fir plantation will be found in the western and more humid parts of the country, or locally on specially favourable soils.

Similar remarks may be made with regard to western red cedar and western hemlock. It is plain, thus, that in Oxfordshire both these species, as well as Douglas fir, endure healthily much more satisfactorily than does Sitka spruce, and even in

relatively western districts such as the lower valley of the River Wye this is still probably true, at least at the lower elevations. There is, plainly, much to be learned still as to the position of all these species: but their efficient use in economic forestry in Britain is hardly possible with any certainty until their reaction to climate and soil, as these vary throughout the country, is adequately understood.

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THE FORESTER TRAINING SCHOOL, PARKEND

THE school in the Forest of Dean celebrated its Fiftieth Anniversary on 22nd July 1954. When the school first opened in 1904 it was the only one of its kind in Great Britain. Other schools were opened by the Forestry Commission after the first war, of which Benmore survives today, and after the second war three more were opened at Thetford in Norfolk, Bettws-y-Coed in North Wales, and Pitlochry in Perthshire. The last named moved recently from Glentress. Entry is by selection from men of good education and aptitude, and the course of two years starting in October covers all aspects of the theory and practice of Forestry. According to the *Thirty-Fourth Annual Report of the Forestry Commissioners for the period ended September 30th, 1953*, 275 men were under instruction then at the five schools (of whom 60 were at Parkend).

Several men now high in the forestry world took their initial training at Parkend, notably the present Director-General, Forestry Commission, and more may follow, but the main object of the training at all five schools is to provide trained staff for the local supervision of forest work. Of some 645 foresters employed in the Forestry Commission, most have been recruited from men trained at one of the five schools. Of the 645 Foresters, 160 were, we believe, trained at Parkend, and there are in addition Parkend-trained men employed in private forestry and in the Colonial Service. Recently men from West Africa have attended courses at the school. The extreme importance of the work being done in selection and training at Parkend and the four other schools to provide the backbone for scientific forestry in Great Britain and elsewhere is thus clear, while the calibre of the gathering at the anniversary showed that this importance is appreciated.

Greetings were received from Mr. C. O. Hanson who started the school in 1904 and whose well-known and invaluable book *Forestry for Woodman* was first published in 1911 to supply a cheap book on scientific forestry for use in the Dean School. In the anniversary edition of the school's journal, *The Deansday Book*, Mr. Hanson wrote: 'Of all the years of my forest life I enjoyed my ten years in the Dean Forest best, because I was actually in the woods so much and also because I had a fine lot of students many of whom became real friends.' Another pleasing reference to the past was made by Mr. A. H. Popert, who, recalling that his father was instrumental in getting the school started, added that he could not have envisaged 'the growth that it was to make nor the influence which its teachings were to have'. And again by Mr. T. Brown, who, looking back on a lifetime spent in the furtherence of forestry, spoke warmly of his experience as a student in the first course held at the school.

The anniversary is important and an opportunity to send good wishes for the future to the Dean School and the four other schools and to wish them all continuing success in the vital work that they are doing.

STUDIES OF SURFACE VEGETATION AND NATURAL REGENERATION IN A MATURE SCOTS PINE WOOD IN ABERDEENSHIRE

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SUMMARY

Observations and data are recorded regarding the changes which take place in the composition and pattern of the surface vegetation immediately following regeneration fellings in a 75- to 85-year-old plantation, composed principally of Scots pine (*Pinus sylvestris* L.). The study covers a period of 5 years, 1946 to 1950. During the same period all natural regeneration of tree species was charted and counted and the results are given. The wood selected for the study was one where it was known that natural regeneration was difficult to obtain. The soil and site factors in the area examined are similar to those in many artificially formed coniferous plantations in the north-east of Scotland.

FOLLOWING preliminary investigations by the writer regarding the presence or absence of natural regeneration of tree species, principally Scots pine (*Pinus sylvestris* L.), at Dunecht Estate, Aberdeenshire (*Forestry*, xix. 41–55), it was decided in 1945 to carry out a seeding felling in a mature stand of almost pure Scots pine on the same estate and study the results obtained when the area was protected against destructive animals. While the main purpose was to observe the quantities and species regenerating naturally as the result of this operation, it was decided at the same time to examine and record the changes occurring in the composition of the surface vegetation of a pinewood following the opening of the canopy for regeneration. An area was chosen where it was known that natural regeneration was difficult to obtain, conditions commonly met with in the case of successfully planted woods in this part of Scotland. The area selected for study may be regarded as typical of the majority of the Scots pine stands of the Dee valley.

The seeding felling was made during the winter of 1945–6 and the area was kept continuously under observation until the whole stand was completely destroyed in the great gale of January 1953.

The observations recorded form part of a larger study of the conditions affecting the natural regeneration of Scots pine in Scotland. They refer to the period 1945–50 when, for reasons later explained, the first phase of the investigations was completed. Numerous plots and sub-plots were laid out to study specific problems. The experiments recorded in this note refer only to those plots designed to study regeneration and vegetational changes where no soil wounding, burning, or manurial treatments were carried out.

DESCRIPTION OF THE SITE AND CROP

The area selected for treatment, 23·65 acres, formed part of a larger 75- to 85-year-old plantation, known as Heather Hill, on Dunecht Estate, Aberdeenshire. Full details regarding the site are given in a previous paper (*Forestry*, xix); the

following is a very brief summary of the most important facts at the time of starting investigations.

Topography. The almost flat top of a hill, elevation 375 to 400 feet, slight slope towards north and west.

Soil. Glacial drift overlying granite. Soil definitely, but not severely, podsolized with a humus layer of 6 to 8 inches, a fairly well-defined leached layer about 1 inch in depth, a russet-brown gritty loam containing many irregularly shaped stones and boulders extending for a depth of 12 to 14 inches before reaching an ochre-coloured, gritty, compacted till.

Climate. The annual rainfall is about 30 inches very evenly distributed. Temperatures range from a maximum monthly average of approximately 60° F. (July) to a minimum monthly average of 35° F. (January). Frost and snow are common between November and March.

Tree crop. Before seeding fellings the crop was an approximately even-aged stand 75 to 85 years old composed of Scots pine 62 per cent., Norway spruce (*Picea abies* Karst) 20·6 per cent., beech (*Fagus sylvatica* L.) 6·5 per cent., oak (*Quercus* spp.) 5·5 per cent., birch (*Betula pubescens* Ehrh.) 3·2 per cent., and larch (*Larix decidua* Mill) 2·2 per cent. The seeding felling carried out between October 1945 and January 1946 removed only Scots pine. Approximately 35 stems per acre were removed with an average volume of about 20 cubic feet per tree. The stocking after the seeding felling was as follows.

Species	*Mean height (feet)*	*Mean quarter girth at breast height (in.)*	*Number of stems per acre*
Scots pine . . .	72	14	22
Norway spruce . . .	70	11¼	19
Beech	60	16¼	6
Oak	49	11½	5
*Birch	48	9¼	3
Larch	70	13½	2
		TOTAL	57

* All the birch was felled and removed during the winter of 1946–7.

The original tree crop in the vicinity of the plots used for the observations recorded was almost entirely coniferous. The following figures show the number and species of seed trees in each $\frac{1}{10}$-acre plot at the beginning of the study and also the numbers and species of the original crop felled and removed in the seeding felling.

	Seed trees left				*Trees removed in seeding felling*		
Plot no.	*Scots pine*	*Norway spruce*	*European larch*	*Total*	*Scots pine*	*Birch*	*Total*
I	3	..	..	3	9	..	9
II	7	2	..	9	..	..	0
III	..	1	..	1	7	3	10
IV	..	3	1	4	1	2	3
V	2	4	..	6	3	..	3

Fig. 1 (Plate II) shows the appearance of the crop at the time of the start of the study.

FIG. 1. Plot I, 1946.

FIG. 2. Plot I, 1947.

PLATE II

Fig. 3. Plot I, 1949.

Fig. 4. Plot I, 1950.

PLATE III

Ground vegetation. Before the opening of the tree canopy the surface vegetation was a complex composed of *Calluna vulgaris* (L.) Hull, *Vaccinium myrtillus* L., *Empetrum nigrum* L., *Deschampsia flexuosa* (L.) Trin., and mosses, chiefly *Polytrichum commune* Hedw. and *Plagiothecium undulatum* (Hedw.) Bry. Eur. *Calluna* and *Vaccinium* were the dominant and most abundant species, each forming pure patches, sometimes of considerable extent and from 12 to 20 inches high. *Empetrum*, though much less frequent, occurred also in pure but smaller patches, as did also the mosses. *Deschampsia*, in a suppressed form, was found extensively, intimately intermingled with other species. Numerous other species occurred occasionally, sometimes becoming locally dominant or co-dominant, e.g. *Oxalis acetosella*, *Holcus mollis*, and *Rumex acetosa*. Considerable patches were completely bare of any vegetation, representing the areas around the stems of the tree crop. Apart from a very few scattered Norway spruce varying in height from 1 foot to 20 feet and even fewer beech, practically no natural regeneration of any tree species was present.

Animals and birds. The area was originally part of the policy woods of the estate and prior to the initiation of these investigations was used as winter shelter for sheep. Rabbits occur but are very rigorously controlled, and for several years all planting on the estate has been successfully accomplished without any wire netting enclosure. Hares are frequent, especially in winter. Red squirrels occur but in small numbers. There are no roe deer. Capercailzie and pheasants are common and are protected for sport. Wood pigeons are numerous in the vicinity.

PLAN OF INVESTIGATIONS

The whole area selected for treatment was carefully marked for a seeding felling in September 1945. Only Scots pines were marked for felling. Four circular plots or 'islands', each one-chain radius, were selected scattered unsystematically throughout the wood and retained in the original stocking (see Fig. 5). Apart from these circular plots, the marking was done to leave approximately sixty trees as seedbearers per acre, evenly distributed. This is a greater number of seedbearers per acre than is usual in a seeding felling with Scots pine, but, as the area is somewhat exposed and forms part of the policy woods of the estate, it was considered desirable to experiment with a comparatively light felling to minimize the risk of wind throw. The felling and extraction were carried out between October 1945 and January 1946. All birch in the original crop was felled and removed in the winter of 1946–7. Very little disturbance of the surface soil occurred. Lop and top was gathered into small heaps and burnt on the area. The whole area was enclosed by a strong fence fitted with sheep netting and all grazing on the area forbidden.

Within this fenced area five plots, each 1 chain by 1 chain square (0·1 acre) and orientated with sides facing north, south, east, and west, were laid out diagonally across the area (see Fig. 5). Each of these plots was very strongly fenced against rabbits. It will be seen from the plan of the area (see Fig. 5) that one of these plots, number II, coincided with one of the four circular plots already mentioned. All the other square chain plots were located in the woodland subjected to a seeding felling.

The information recorded in this note refers only to the five square chain plots. These plots were kept under very careful observation and completely charted each

year, up to and including 1950, to record the surface vegetation and the occurrence of any natural regeneration of tree species.

The conditions, particularly of light and moisture, varied to some extent in each plot according to the presence or proximity of seed trees. No satisfactory

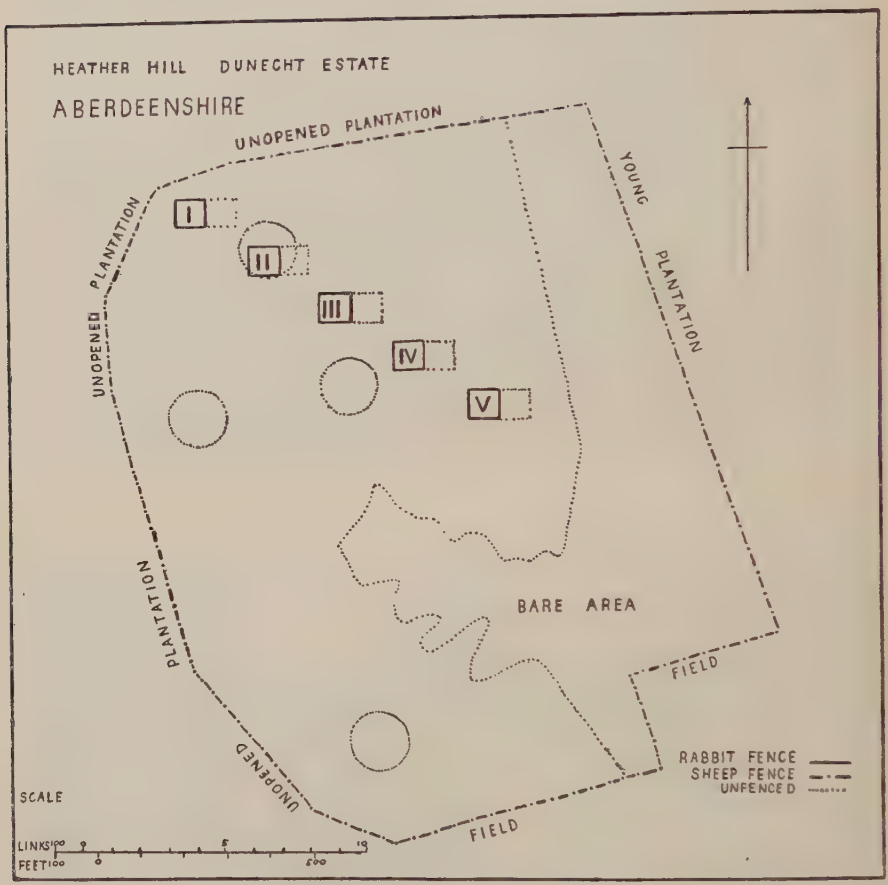


Fig. 5. Location of experimental plots.

method was devised for measuring these differences. Apart from plot II, in which conditions were obviously different from those in the others, the results observed and depicted in the other four plots when taken together give a reasonable picture of the general changes occurring in the opened woodland generally and form an interesting comparison with the more static conditions in plot II.

METHODS OF RECORDING RESULTS

The purpose of this study was twofold, namely to observe the changes in the composition or pattern of the surface vegetation and to record the occurrence, survival, or disappearance of any tree regeneration. To do this each of the square chain plots was treated in a similar way. Each side of the square was marked with

tabs at 6-foot intervals and the whole plot subdivided by tapes into 6-foot squares for charting. The ground vegetation in each 6-foot section was carefully charted on squared paper showing the limits of the dominant components of the surface vegetation or of a characteristic and recognizable complex.

During the period of study very considerable colonization by birch and rowan (*Sorbus aucuparia* L.) occurred, eventually, in the later years, constituting a second layer or story to the vegetation and, along with coppice growth from stumps, casting considerable shade. An attempt was made on the field charts to indicate the position of birch and rowan seedlings as they appeared from year to year, but when they became sufficiently dense as to cast shade and influence the vegetation below, the outline of the shaded patch was separately charted.

Any established regeneration of tree species at the time of making the first charts in 1946 was entered on the charts and the individual plants pegged on the ground with metal pegs so that subsequent recruitment of tree species could be followed and charted.

Finally, the position of all living trees of the original crop and the position of all stumps of felled trees were also charted.

The first charts for each of the five square chain plots were made by the writer in September 1946 and each plot was recharted by him at the same time of year for five consecutive years resulting in a series of twenty-five charts.

From the field charts tracings were made, giving the boundaries of the clearly recognizable vegetation types which were then coloured, using the same colours each year, so that the changing pattern of the vegetation could be more easily seen and compared. The field charts and coloured tracings give the picture of the changes much better than a description, tables, or diagrams but, unfortunately, it is impracticable to reproduce them here.

Figs. 1 to 4 in Plates II and III show the general appearance of plot I in the summer of the years 1946, 1947, 1949, and 1950.

CHANGES IN THE SURFACE VEGETATION

Charting on such a scale and in such a manner as described presents several practical difficulties. It was often by no means easy to determine the limits of any particular type or species and the annual charts cannot be considered sufficiently accurate to allow direct comparison of the boundaries of individual types. However, as the charting was done by the writer in the same way at the same time of the year, a useful and reasonably accurate picture of the changes emerges after a period of time and a very fair assessment of these changes can be measured.

Although a comparison between the 1946 and 1950 charts indicates the changes which have occurred in that 5-year period, it does not tell the full story. Certain species, particularly *Deschampsia*, exhibit fluctuation in status within the period. Again, the developments of a layer of woody growth, as birch and rowan thicket, complicates the problem. Indeed it was the development of such a layer which made the continuation of this method of study impossible after 1950. Because of the difficulties in the reproduction of numerous field charts the present note has

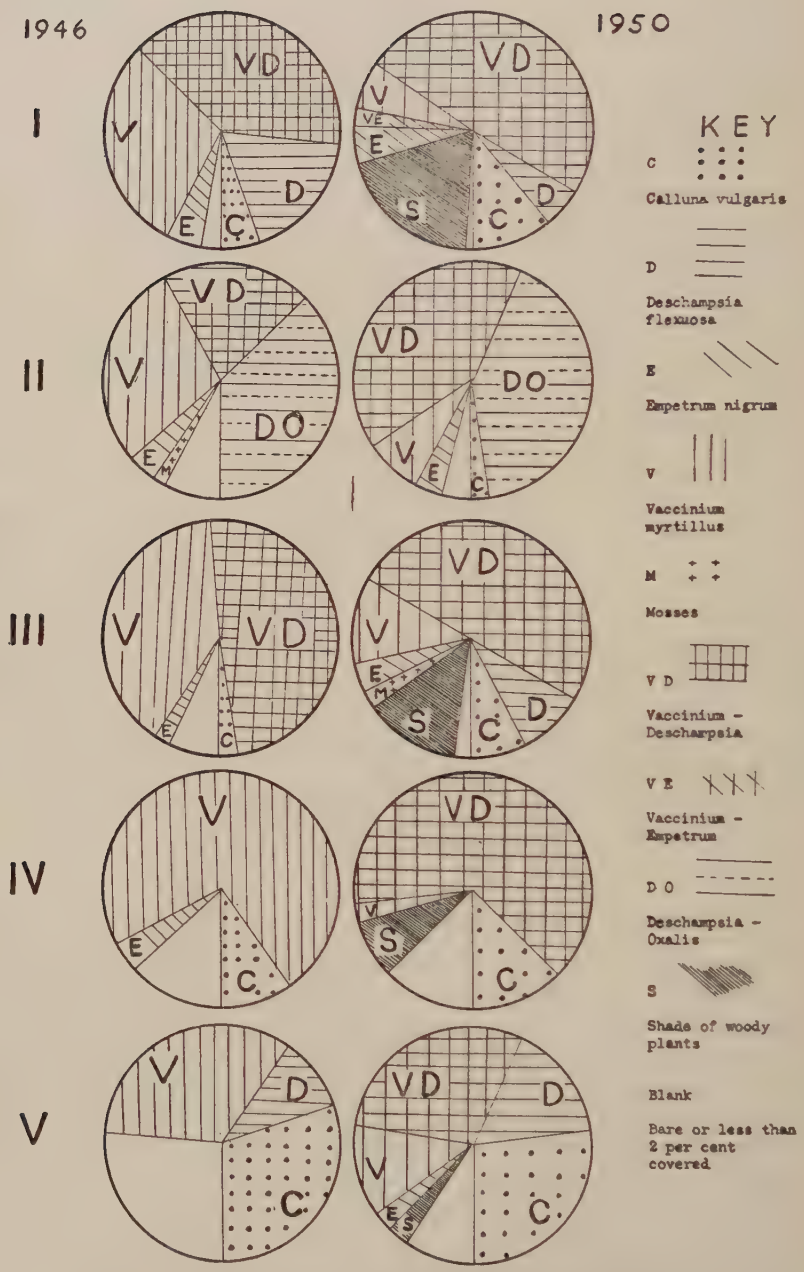


FIG. 6. Vegetation types by area in plots I to V in 1946 and 1950.

been limited to a comparison of the conditions at the beginning and end of the period of study.

As an alternative to reproducing the charts, the areas covered by the various vegetative types in each of the five plots charted in 1946 and 1950 were measured. This was done by contact printing the coloured charts referred to and then cutting out and weighing the different pieces of the jig-saw representing a particular species or type. In this way the total area of each type, expressed in square yards, and the percentage area per plot per year was calculated. The results are given in Table I. The coefficient of variation of these ten weighings was $\pm 2{\cdot}15$ per cent.

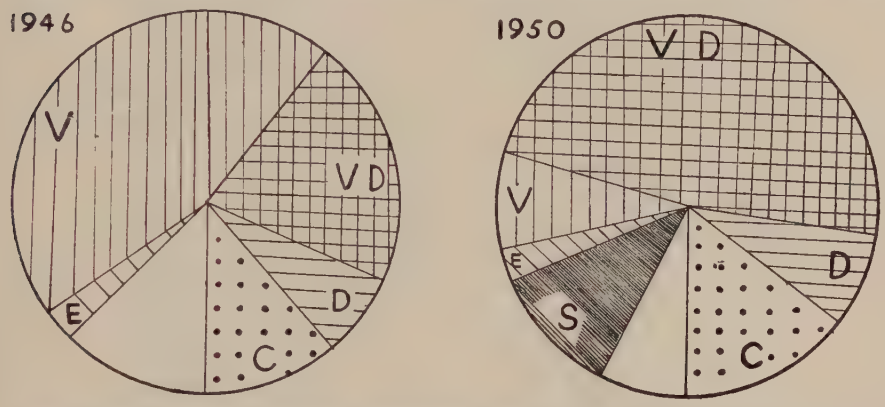


Fig. 7. Change of area of vegetation types between 1946 and 1950. Average for plots I, III, IV, and V. Symbols as in Fig. 6.

It is obvious from this table that the vegetation in plot II is fundamentally different from that in all the other plots. This is interesting, as this plot was the only one which was situated in an untreated portion of the original tree crop. The most remarkable difference in the vegetation of plot II in 1946 was the presence of *Oxalis acetosella* in intimate association with *Deschampsia flexuosa*. In 1950 very little change had occurred in the vegetation of this plot as compared with that of the other plots.

Table II shows the percentage increase or decrease in area covered by the various components of the vegetation during the 5-year period 1946 to 1950, considering the other four plots together.

Fig. 6 represents diagrammatically the areas of types covering more than 2 per cent. of the area in each of the plots as charted in 1946 and 1950. Fig. 7 gives similar information for all plots, except plot II, taken together.

OBSERVATIONS ON VEGETATIONAL CHANGES

An examination of the yearly charts of each plot reveals much of interest, but the following brief notes deal only with the more important changes in the vegetation. Plot II, as already explained, exhibits a different pattern of vegetation from the other plots and consequently is omitted from these observations unless specially mentioned.

TABLE I. *Percentage area covered by vegetation types, &c., in each $\frac{1}{10}$ acre plot in 1946 and 1950*

Plot	*Year*	*Calluna vulgaris*	*Deschampsia flexuosa*	*Empetrum nigrum*	*Vaccinium myrtillus*	*Mosses*	*Epilobium angustifolium*	*Rumex acetosella*	*Rubus idaeus*	*Agrostis tenuis*	*Holcus mollis*	*Vaccinium–Deschampsia*	*Vaccinium–Empetrum*	*Deschampsia–Oxalis*	*Deschampsia–Mosses*	*Stems of living trees*	*Stumps of felled trees*	*Bare*	*Shade of birch and rowan*
I	1946	5·0	17·5	4·9	30·6	..	..	..	..	..	..	38·9	..	..	..	0·2	0·5	2·4	..
	1950	11·2	5·2	5·2	6·3	..	..	..	..	..	..	48·7	2·5	..	..	0·3	0·4	..	20·3
II	1946	0·3	..	4·4	27·0	2·0	..	..	..	..	..	20·8	..	37·5	..	0·7	..	7·0	..
	1950	2·1	..	4·2	8·6	1·1	0·3	..	..	..	..	39·8	..	41·5	..	0·8	..	0·5	1·3
III	1946	2·3	..	2·2	39·5	..	..	..	..	..	..	48·5	..	..	..	0·1	0·5	6·0	1·0
	1950	7·4	9·5	4·1	12·2	2·6	..	..	..	..	..	49·6	..	..	..	0·1	0·4	0·3	13·8
IV	1946	9·8	..	4·2	72·7	..	..	..	..	..	..	..	..	..	1·4	0·2	0·3	10·7	0·7
	1950	13·0	1·8	1·6	2·4	0·4	..	..	..	..	..	63·9	..	..	..	0·3	0·2	8·7	7·6
V	1946	29·7	10·6	1·0	34·1	..	..	0·9	..	..	..	..	..	..	..	0·8	0·1	22·6	0·1
	1950	27·0	17·0	2·2	11·7	..	..	0·9	0·1	1·8	0·6	28·7	..	..	..	0·6	..	6·6	3·0

Calluna vulgaris. The increase in the proportion of dominant heather in the vegetation, though not very striking, is quite definite and occurred gradually and evenly. Plants present at the beginning of investigations increased their size and there was also a considerable number of seedlings.

TABLE II. *Percentage increase or decrease in area of vegetation types, &c., between 1946 and 1950 (average for plots I, III, IV, and V)*

	% +	% −
Calluna vulgaris	2·95	..
Deschampsia flexuosa	1·35	..
Empetrum nigrum	0·21	..
Vaccinium myrtillus	..	36·07
Mosses	0·74	..
Rumex acetosella	0·0	0·0
Rubus idaeus	0·2	..
Agrostis tenuis	0·45	..
Holcus mollis	0·15	..
Vaccinium–Deschampsia	25·9	..
Vaccinium–Empetrum	0·62	..
Deschampsia–Mosses	..	0·35
Stems of living trees	..	0·01
Stumps of felled trees	..	0·11
Bare	..	6·5
Shade of birch and rowan	10·7	..

Deschampsia flexuosa. It will be observed that this grass is sometimes charted as a dominant pure type and sometimes as a co-dominant with *Vaccinium* and other species. It was comparatively easy to differentiate the pure patches of this grass. The results as presented do not, however, convey a complete picture of the part played by this component in the changing pattern of the vegetation during the period of the study. In 1946 the area charted as pure *Deschampsia* was in no case very great, although in all plots this grass was present in a suppressed form and intimately mixed with *Vaccinium*. By the summer of 1947 the appearance of the vegetation had been completely changed by the luxuriant growth of the flowering hair grass, which was then 2 feet in height (see Fig. 2). This species is the quickest in the vegetational complex to respond to the opening of the tree crop, the year 1947 representing the climax of its growth. Thereafter the charts show a steady decline in the size of the patches originally charted. It will be observed, however (see Fig. 7), that, considering all comparable plots together, the area represented by pure dominant *Deschampsia* at the end of the 5-year period is much the same as at the beginning. The position in space of this component has, however, changed, and in 1950 it is found chiefly on areas which originally were bare of vegetation. Of all the plants competing for these bare patches *Deschampsia* was generally the first to take possession.

Vaccinium myrtillus. In the 1946 charts there was little difficulty in differentiating and charting pure patches of dominant *Vaccinium*. In subsequent years this became much more difficult as the *Vaccinium* became increasingly invaded

by *Deschampsia*, resulting in a complex which was separately charted. The most noticeable change, in fact, in the general pattern of the vegetation during the 5 years of observation is the marked reduction in the area indisputably occupied by pure *Vaccinium*. This very noticeable change is exhibited by all plots, but much less so in the more heavily shaded conditions of plot II. It appears certain that in the conditions of these investigations the status of *Vaccinium* in the ground flora is quickly and profoundly changed. The ground lost by *Vaccinium* is apparently occupied, at least to begin with, more readily by *Deschampsia* than by *Calluna*.

Empetrum nigrum. This species represents a small part in the ground vegetation pattern, but it is present in the charts of all the plots. It tends to form pure patches and very little fluctuation of area occupied by it was observed during the period.

Bare areas. In all plots there is a marked reduction in the area of bare, unoccupied ground following the opening of the tree canopy. The species most active in occupying vacant ground was *Deschampsia*, although in plot V comparatively small colonies of *Holcus* and *Agrostis* have taken possession.

Shade of birch and rowan. In all plots, but much less in plot II, as would be expected, there was in the 5 years very marked natural regeneration of birch and rowan. By 1950 this had established itself so completely as to form, over a considerable area, another layer of vegetation casting sufficient shade to affect the ground vegetation below (see Fig. 4). By this time this woody thicket layer had reached a height of up to 6 feet, making further charting on the original system impossible. The significance of this woody tree layer is dealt with later in connexion with natural regeneration, but it should be mentioned that invasion by rowan when a pine crop is opened up is a common feature in Scotland.

Other components of the vegetation. None of these appears to be sufficiently important as to need special comment. In all cases the area occupied is very small and no obvious significance is attached to any.

REGENERATION STUDIES

In August 1946 all established tree regeneration was carefully entered on the charts of each plot and pegged with a metal peg. Established regeneration comprised all tree seedlings 1 year or over in age at the time of making the first examination. Since the seeding felling had been made in the previous winter, very little established regeneration was present; the species and numbers are given in Table III. It will be observed that practically all the species are shade bearers, 70 per cent. being beech and 24 per cent. Norway spruce. No established Scots pine occurred, and the light-demanding birch and rowan were present only as recently germinated seedlings. A very noticeable feature at this time was the large number of Scots pine seedlings which had just germinated. These seedlings were not easily seen because of the ground vegetation, but careful examination showed that everywhere, both inside and outside the plots, germination was profuse. It was impracticable to count or mark all such recently germinated seedlings within each plot, but one area of 200 square yards outside, but adjacent to, plot I was carefully counted and pegged, so that survival might be studied. This area showed

a total of 127 Scots pine seedlings, corresponding to 3,073 per acre, which had germinated in 1946, very evenly distributed over the area. The seed crop of Scots pine falling in the spring of 1946 on the area was not a heavy one. The same area

TABLE III. *Natural regeneration per $\frac{1}{10}$ acre plot per year showing annual recruitment and mortality*

		1946	*1947*		*1948*		*1949*		*1950*	
Plot I	Beech	5	+3−0	8	+4−0	12	+0−3	9	+0−0	9
	Norway spruce	1	+0−0	1	+0−0	1	+0−0	1	+0−0	1
	Silver fir	1	+1−0	2	+0−0	2	+1−0	3	+0−0	3
	Scots pine	..	..		+18	18	+9−5	22	+5−2	25
	Total	7		11		33		35		38
Plot II	Beech	8	+0−0	8	+9−0	17	+1−1	17	+3−0	20
	Norway spruce	4	+2−0	6	+0−0	6	+1−0	7	+0−0	7
	Scots pine	..	..		+1	1	+0−0	1	+0−0	1
	Total	12		14		24		25		28
Plot III	Beech	23	+11−2	32	+17−4	45	+6−5	46	+3−0	49
	Norway spruce	1	+1−1	1	+1−0	2	+1−1	2	+1−0	3
	Silver fir	..	+1	1	+1−0	2	+1−0	3	+0−0	3
	Scots pine	..	..		+30	30	+18−8	40	+9−2	47
	European larch	..	..		+3	3	+2−2	3	+0−1	2
	Total	24		34		82		94		104
Plot IV	Beech	9	+11−0	20	+22−4	38	+1−8	31	+6−0	37
	Norway spruce	9	+0−0	9	+2−0	11	+3−0	14	+3−0	17
	European larch	2	+3−1	4	+17−0	21	+14−4	31	+4−2	33
	Silver fir	..	+1	1	+0−0	1	+2−0	3	+1−0	4
	Scots pine	..	..		+2	2	+3−1	4	+1−0	5
	White beam	..	..		+1	1	+0−0	1	+0−0	1
	Total	20		34		74		84		97
Plot V	Beech	4	+2−1	5	+14−0	19	+4−0	23	+0−3	20
	Norway spruce	2	+2−0	4	+1−0	5	+2−1	6	+1−0	7
	Oak	1	+0−0	1	+0−0	1	+0−0	1	+0−0	1
	White beam	..	+2	2	+0−2	0	..		+1	1
	European larch	..	..		+5	5	+0−1	4	+1−1	4
	Scots pine	..	..		+4	4	+3−1	6	+1−0	7
	Elder	..	..		+1	1	+0−1	0	..	
	Douglas fir	..	..		..		+1	1	+0−0	1
	Ash	..	..		..		..		+1	1
	Total	7		12		35		41		42

was very carefully re-examined at the same time of the year in 1947 when only 15 of the original 127 seedlings were alive, a mortality of 88 per cent. Observations in other parts of the experimental area confirmed this very high loss.

Another feature of the regeneration conditions in 1946 was the large numbers

of birch and rowan which had germinated since the opening of the canopy and which, by August of that year, were already well rooted. These were too numerous to peg, but their position was entered on the vegetation charts. Each year during August or September the seedlings of all tree species, other than birch and rowan, were carefully charted and pegged, while the presence of birch and rowan was indicated in the charts. The results of the annual regeneration counts for all species, other than birch and rowan, are given for each plot in Table III. It will

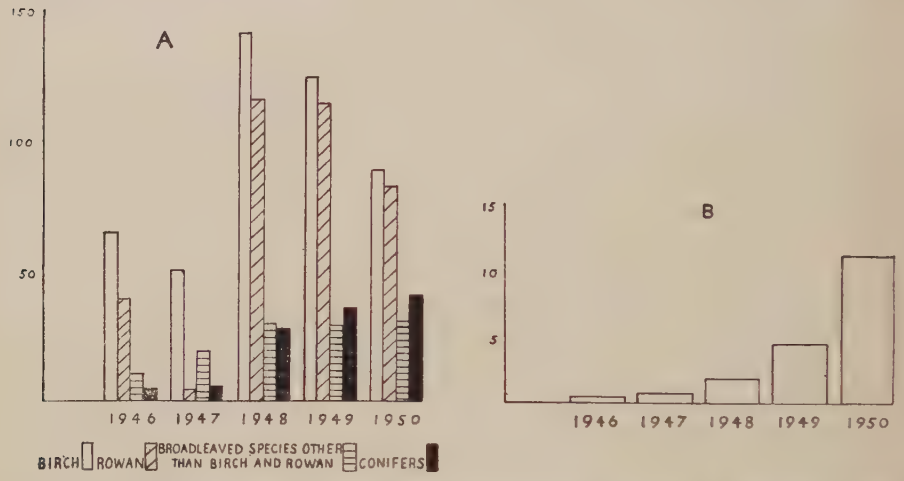


Fig. 8a. Average number of naturally regenerated tree species present per $\frac{1}{10}$ acre plot per year.
Fig. 8b. Average percentage area shaded by birch and rowan regeneration.

be observed from this table that in every plot there was a small but gradual net annual increase in the number of established seedlings. In no year, however, during the period of observations was the germination anything like so profuse as it was in 1946 immediately after the opening of the canopy.

As already mentioned, the rapid and marked invasion of the area by birch and rowan presented special difficulties regarding the recording of results. By 1948 these species were beginning to form patches of regeneration in which it was not possible to chart individual stems. At the same time these groups cast considerable shade while in leaf and were charted as a separate shade casting layer. In Fig. 8a the numbers of tree seedlings, expressed as the average for all plots except plot II, are shown for each year. In view of the special problems presented by the birch and rowan, the area charted as shade cast by these species is also given as Fig. 8b. The falling off in the numbers of individuals of these two species is compensated by the marked rise in shade cast, which actually represents the area covered by regeneration of these species which has reached the thickest stage. In connexion with Fig. 8 it must be mentioned that in 1947 it was particularly difficult to find seedlings which had germinated earlier in this year because of the rank growth of *Deschampsia*. Without doubt some of these were missed in the charting and only discovered in the following year. In addition 1947 was a very bad seed year for

Scots pine in the area. These facts explain the comparatively small numbers of seedlings recorded for 1947. It must be recorded that throughout the period of the observations no heavy seed crop of Scots pine occurred. Conditions affecting natural regeneration in plot II were completely different from those in the other plots. It will be seen from Fig. 5 and the detailed description of the plots that none of the original tree crop had been felled in this plot and, as might be expected, the regeneration in the heavier shade was much less than in the other plots and was confined, practically entirely, to shade-bearing species. Consequently, in considering regeneration results, as shown in Fig. 8A, plot II has been eliminated and the other four plots considered together.

It became obvious during the progress of these observations that the tree regeneration within the specially fenced square chain plots was better than that found outside the plots but within the remainder of the experimental area. The only difference as regards protection was that, while the whole area was fenced against sheep, only the plots were completely fenced against rabbits. During the course of the investigations occasional rabbits were observed within the perimeter fence but, in keeping with the general policy on the estate, the numbers of those animals were kept in very complete control. There was ample evidence of hare outside the plots. These animals are common and the perimeter fence would not have excluded them. In the summer of 1948 severe damage by voles was observed. A remarkable feature of this attack was the large number of rowan seedlings, about 18 inches to 2 feet in height, which were killed by having the stem at ground level completely girdled. Rowan was very obviously preferred by these rodents, although several beech seedlings were also killed. No case of damage to any coniferous species by these animals was observed. Capercailzie and pheasants were constantly seen and both species nested on the area. The small size of the plots and the height of the surrounding rabbit fence made it difficult for these heavy birds to alight within or take off from the plots.

In order to compare results inside and outside the rabbit-proof fenced plots another series of plots of the same size, i.e. $\frac{1}{10}$ acre, were laid out in 1950, immediately adjacent to the original plots on the east side of each (see Fig. 5), and the regeneration of all tree species, other than birch and rowan, charted. The results of these counts and the position of the regeneration is shown in Fig. 9. It is very obvious that the regeneration is markedly poorer outside the rabbit-fenced plots.

An attempt was also made to see if there was any correlation between the occurrence of tree seedlings and the particular ground vegetation at the place of germination and survival. If seedlings of all species are considered, it would appear that regeneration is very similar on ground inhabited by *Deschampsia*, *Vaccinium*, and a *Vaccinium–Deschampsia* complex but noticeably less frequent on either *Calluna* or *Empetrum*. If Scots pine regeneration only is considered, there appears to be a marked preference for the *Vaccinium–Deschampsia* or pure *Vaccinium*, after that for pure *Deschampsia*, while there is a marked reduction in numbers on *Calluna* or *Empetrum*.

Mention must be made of the occurrence, among the regeneration obtained (see Table III), of species which were completely absent from among the seed-

bearers left on the area. This applies to silver fir (*Abies alba* Mill.) and Douglas fir (*Pseudotsuga taxifolia* Britt.) among the conifers, and to rowan, white beam (*Pyrus*

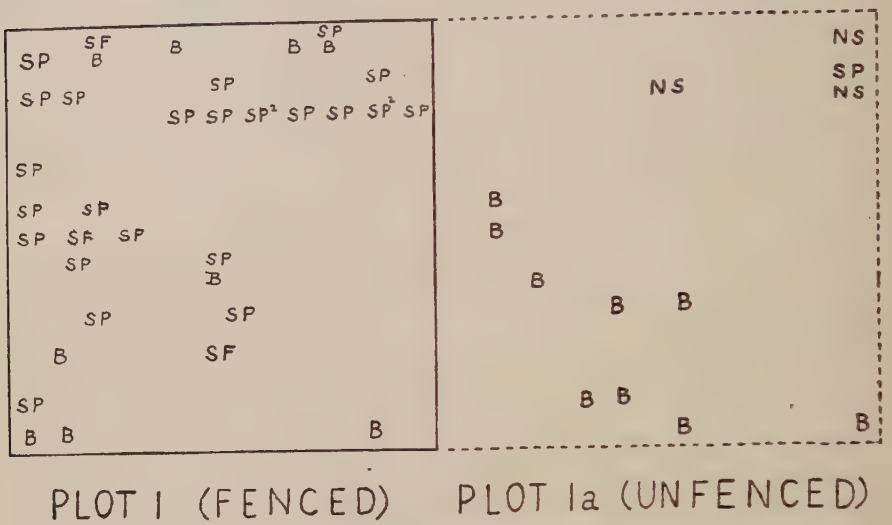
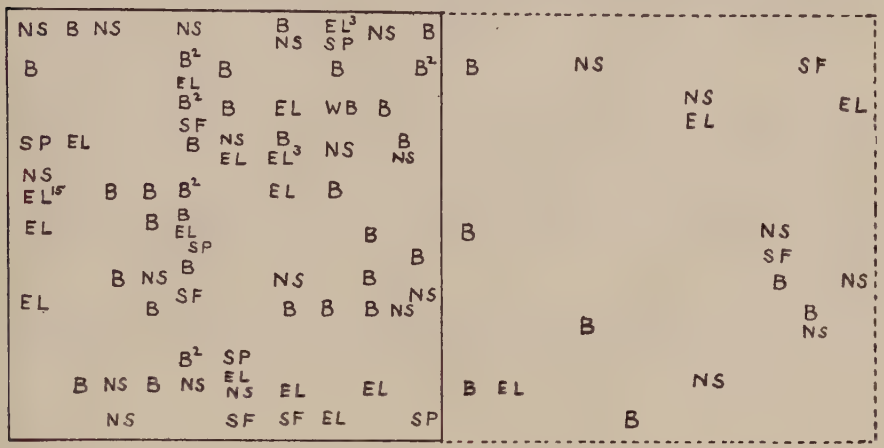


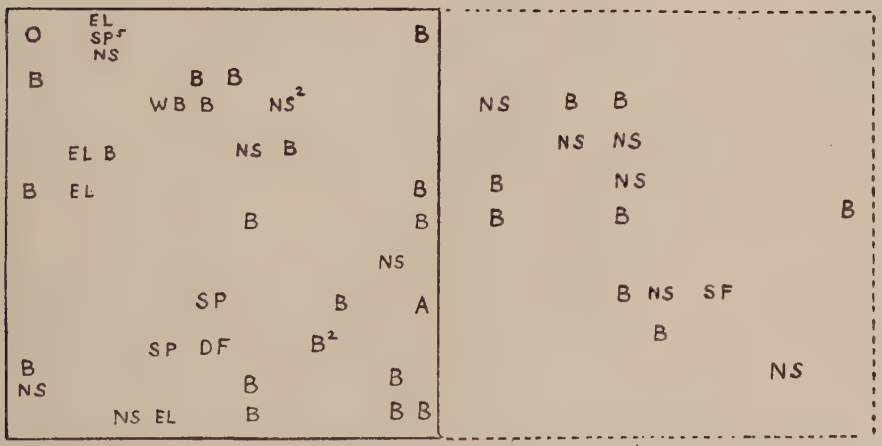
FIG. 9. Comparative natural regeneration inside

SP = Scots pine EL = European larch O = Oak NS = Norway spruce

aria Ehrh.), elder (*Sambucus nigra* L.), and ash (*Fraxinus exelsior* L.) among the broadleaved trees. The nearest known Douglas fir seedbearers, two trees approximately 85 feet high, were over 1,000 feet distant to the south-west. The nearest silver-fir parents were approximately 450 feet away to the north. Five rowan trees

from 15 to 35 feet high and bearing fruit were found outside the perimeter of the area of the seeding felling to the north, the nearest approximately 300 feet from





and outside rabbit fenced plots in 1950.

SF = Silver fir DF = Douglas fir A = Ash B = Beech WB = White Beam

the plots. No white beam, elder, or ash was discovered within 1,000 feet of the plots. The rapid invasion of the area by rowan, in particular, indicates a very important role played presumably by birds in seed dissemination in this part of Scotland.

OBSERVATIONS ON REGENERATION RESULTS

Among the many interesting deductions which may be made from this study the following appear to be the most important.

Germination of tree species, especially Scots pine, was very markedly greater in the first year after opening of the original stand, but the mortality among these seedlings was extremely high. This mortality is almost certainly due principally to the presence of a close ground vegetation which makes penetration by the seedling roots to mineral soil difficult, and which also competes severely for moisture and nutrients. But even when pine germinated on areas bare of vegetation, the seedlings rarely survived the first year. The undisturbed humus layer appears to be very uncongenial to establishment. Adverse moisture conditions rather than adverse light conditions seem to be the main cause of death.

The phenomenal and rapid colonization of the area by birch and rowan was the most significant feature of the regeneration. The marked success of these pioneer species in establishing themselves, as compared with the coniferous species, is very noticeable.

In spite of the rapid invasion of the area by pioneer tree species, there was a small but consistent annual increase in recruitment of coniferous species, especially Scots pine, during the first 5 years following the opening of the canopy.

Although the mother trees in the area were predominantly Scots pine, the resulting regeneration showed an interesting mixture and variation of species.

In the complicated soil vegetation covering it is difficult to say that any one component was markedly more favourable than another as regards the establishment of regeneration.

The importance of light in determining the amount, and still more the kind, of regeneration is abundantly proved. The indications are that more open light conditions than those obtaining would have resulted in a larger number of Scots pine regenerating successfully.

The part played by animals and birds in the dissimination of tree seed and also in the destruction of natural regeneration is imperfectly known. In soil and climatic conditions which make the rapid and successful establishment of desirable regeneration difficult, protection against destructive animals and birds is particularly important.

CONCLUSION

In conditions such as existed in the area of examination the general conclusion is that, while the site is in every way suitable for the growth of a stand of Scots pine, the natural regeneration of such a stand, unless specially assisted, is difficult and uncertain and can only be obtained after a period of succession by other species, particularly birch and rowan. There is reason to believe that, provided adequate protection is provided against destructive animals and birds, regeneration composed of economically valuable species could be obtained in time, but the indications are that the crop would be less pure than the original and would contain a mixture of conifers and broadleaved trees.

In other conditions, notably if the soil is more sandy and the vegetation cover-

ing more simple and more scanty, natural regeneration of Scots pine can be much more easily and quickly obtained. The conditions in the area examined are, however, very typical of the majority of the artificially formed Scots pine plantations on glacial drift in the north-east of Scotland.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge with sincere thanks the facilities afforded to him by the Right Honourable the Viscount Cowdray, the owner; Mr. D. D. Laurie, the factor; and Mr. C. Y. Ross, the head forester of Dunecht Estate. The co-operation and assistance given over a long period of time alone made the study recorded in this note possible.

Grateful acknowledgement is also made to the Carnegie Trust and the University of Aberdeen for grants towards the cost of publication of this paper.

THE BRITISH ASSOCIATION, OXFORD, 1954

The British Association for the Advancement of Science last met in Oxford in 1926 and it was during that meeting that our own Society met and adopted its first Constitution. The Forestry Sub-section in 1954 had a full programme and the following papers were read.

Chairman's Address:

Mr. W. E. Hiley, 'The influence of forest economics on forest policy'.

Joint session with Section D—Zoology. Animal populations and forestry:

Mr. G. H. Thompson, 'Introduction to the session'.
Mr. F. Courtier, 'Studies of grey squirrel populations'.
Mr. H. N. Southern, 'Mice and vole populations.'
Dr. Myles Crooke, '*Bupalus piniarius* L., the pine looper; a British forest insect problem'.
Prof. G. C. Varley, 'Insect defoliators of oak'.

Joint session with Section K—Botany. The interactions between acid soils and forest trees:

Mr. M. V. Laurie, 'Introduction: the forester's viewpoint'.
Dr. G. W. Dimbleby, 'Fundamental studies of problems associated with heathland afforestation'.
Prof. L. G. Romell, 'The competitional factor in the formation of mor'.
Dr. S. D. Garrett, 'Some effects of soil acidity upon soil-borne diseases of forest trees'.
Dr. J. L. Harley, 'Non-parasitic associations of roots and micro-organisms'.
Dr. L. Leyton, 'The relationship between the mineral nutrition and the growth of forest trees'.
It is hoped to publish Professor Romell's paper in a future number of *Forestry*.

The management of beechwoods under the Chilterns Project:

Mr. O. J. Sangar, 'The Chilterns Project'.
Mr. J. M. B. Brown, 'The assessment of site potentiality'.
The Rt. Hon. The Earl of Buckinghamshire, 'The viewpoint of the private owner in the Chilterns'.

The private estate sawmill:

Capt. G. C. Wolryche-Whitmore, 'Estate sawmills'.
Lt.-Col. A. V. Spencer, 'The case against estate sawmills'.

Miscellaneous:

Dr. A. J. Rutter, 'Methods of measuring growth in young conifers and their application in forest ecology'.
Mr. J. N. R. Jeffers, 'Measurement of young conifers in nursery experiments'.
Mr. A. D. Miller, 'Some silvicultural and economic aspects of rehabilitation of broad-leaved woodlands'.
Mr. R. F. Wood, 'North-west American coastal forests'.

Excursions were made to the Parmoor beechwoods in the Chilterns and the Bathurst Estate woods in the Cotswolds, under the leadership of Mr. J. E. Garfitt; to the Forestry Commission Research Station, Alice Holt Lodge, Farnham; to Wytham Woods and to Kennington Nursery, near Oxford.

A LITTLE-KNOWN BORER IN IMPORTED SOFTWOOD; *SERROPALPUS BARBATUS* SCHALL. (COLEOPTERA, MELANDRYIDAE). REVIEW OF LITERATURE AND RECENT OCCURRENCES IN GREAT BRITAIN

By J. D. BLETCHLY

(*Forest Products Research Laboratory*)

SUMMARY

A brief account is given of the biology and world distribution of this comparatively unimportant timber insect, which is responsible for a type of damage indistinguishable from that caused by wood-wasps of the family Siricidae, and with which it may have been confused in the past. The presence of such damage is of interest in connexion with the recently intensified quarantine measures in Australia to prevent the introduction of *Sirex* spp. in imported timber. Recent records have been associated in most cases with whitewood (*Abies* spp.) imported from Yugoslavia, but there is no evidence that this beetle has become established or is an important timber pest in this country.

INTRODUCTION

APART from two instances (7), *Serropalpus barbatus* Schall. has not been noted in Great Britan until recently. In 1949 a sample of fir (*Abies* spp.), submitted to the Forest Products Research Laboratory for examination, was found to have been damaged by this beetle. Since that date further instances of damage to imported softwoods have come to the notice of the Laboratory in the course of advisory work.

The type of defect caused by this insect, which confines its attention to softwoods, is indistinguishable from damage by wood-wasps of the family Siricidae. In view of the strict quarantine measures recently enforced in Australia (3) to prevent the introduction of *Sirex* spp. in imported softwoods and because of the close similarity of the two types of damage, a review of world literature on the habitat, distribution, and life-cycle of *S. barbatus*, together with a brief account of records of its occurrence in the United Kingdom, where it is comparatively rare, may be of value and serve to draw attention to this insect in the hope that further details may be forthcoming concerning its status in this country.

REVIEW OF LITERATURE

Geographical range

Serropalpus barbatus was described by Erné (5) as causing serious damage in healthy standing firs in the Vosges. Wachtl (19) found it in Austria and, unaware of the earlier literature, claimed responsibility for describing its significance as a forest pest in his contribution to the Vienna World Exhibition of 1873. More recent literature reveals a wide distribution in central, north, and south Europe

(6), including France, Norway and Sweden (7), and northern Italy, Greece, Russia, and Siberia (11), but it is not indigenous in Great Britain (7). Amongst other authorities, Stark (18) mentions the distribution in the province of Leningrad, whilst Dominik (4) states the species is found at Irkutsk in Siberia. It is included in the North American fauna by many authorities and a wide distribution is given (10): the correctness of the specific identification has, however, been questioned (14).

Habits and life-history

1. *Adult.* The beetle has been described in some detail (6, 7, 13): it is blackish-brown, elongate and narrow, antennae and legs are reddish-brown, maxillary palps large with a club-shaped terminal joint, and the antennae are up to half the body length in males. Length 8 to 18 mm.

The beetles are nocturnal and lie hidden in the daytime: if at night they are exposed to light they again become quiescent, but are otherwise very active (4, 13). Emergence takes place only in fine weather; in long spells of rain a large proportion fail to emerge and die in the pupal cells (4). The normal length of adult life is not known, but under 'artificial conditions' (not defined) it is given as up to 21 days (4). Copulation takes place on the ground or a stump, lasts from 1 to 3 minutes, is repeated several times, and occurs at night (4, 12).

The time of the flight period appears to be variable, probably related to climatic factors. Wachtl (19) states it can be from spring to autumn; Dominik (4) states that beetles swarm in the Beskid area of Poland in July, August, and September; Saalas (17), presumably referring to Finland, states imagines are found from June to August; and Stark (18) (quoting Varshalovich) gives the flight period in the Leningrad area as the end of June to mid-July.

2. *Egg.* The eggs are white, about $1{\cdot}2 \times 0{\cdot}2$ mm.; the average number laid is unknown, but dissection suggests a potentiality of up to 170 (4). Eggs may be laid on stumps, on sickly standing or on felled trees (13); but, according to Wachtl (19), only where at least some of the bark is present, which is apparently also the opinion of Saalas (17). Dominik (4) states that they are laid in cracks and crevices in wood. Egg-laying occurs at night (12).

3. *Larva.* This has been fully described (19). It is of a characteristic shape, about $\frac{1}{2}$ to 1 inch long, tapering somewhat towards the ends, particularly posteriorly, and widest at the centre owing to slight dorso-ventral flattening. The head has a large labrum, three segmented antennae, ocelli absent or unpigmented, and the mouth-parts are heavily chitinized. The prothoracic segment is distinct and of greater width than the mesa- and metathorax combined which resemble the abdominal segments in appearance. The well-developed legs are about three times the length of the antennae. Perhaps the most characteristic feature is the presence on the terminal segment of two dorsally curved brown urogomphi which immediately distinguish this larva from *Sirex* spp. armed with a single spine.

The duration of the larval stage is variously considered to be 2 years (1, 4, 19) or 3 years (5, 11) and apparently varies with the moisture content of the wood (8).

4. *Pupa.* This stage has been described in detail only by Wachtl (19) and is

apparently characterized by the following features: well-developed pectinate maxillary palps, the mesasternum divided into two parts by a projection from the prosternum, the ninth abdominal tergite with four well-developed spines arranged transversely but not equidistant and the eighth with a dorsal pectinate elevation with a central constriction and four very large spines.

Pupation takes place near the surface in sound wood (4, 13), but in decayed wood it may be at a considerable depth (4). Dominik found in Poland that pupation commenced in June and lasted from 12 to 24 days, emergence occurring after a lapse of several more days.

5. *General.* Little is known about predators and parasites, but Dominik includes a few observations in his paper (4).

Economic importance

Wachtl (19) was of the opinion that this insect was mainly if not entirely confined to silver fir (*Abies alba*): Escherich (6) agrees that silver fir is preferred, but states that in its absence spruce may be attacked, particularly in Sweden and east Prussia. Stark (18) (quoting Varshalovich) states that in the Leningrad area only spruce is attacked. Dominik (4) and Reitter (16) agree that both fir and spruce are susceptible. Gusev and Rimskij-Korsakov (9) give juniper (*Juniperus communis*), two species of spruce (*Picea abies* and *Picea orientalis*), and silver fir (*Abies alba*) as host trees, *Sirex* being also found in the same species of the last two genera. In America, Blackman and Stage (2) give balsam, hemlock, larch, and spruce as susceptible.

Authorities, with the exception of Erné (5), are agreed that attack is confined to sickly standing trees and sound felled timber, but fire-damaged trees may also be attacked (17). Dominik (4) described a large-scale infestation following storm damage in Poland.

It seems that attack is most often found in the bole but, according to Dominik (4), branchwood thicker than 4 cm. or the exposed roots of wind-blown timber may also be damaged. Unlike Erné (5), he considers that attack may be found in decayed wood; Dominik believes attack originates in sound wood but, rather than change its habitat, this insect will continue to breed in a log until fungal decay has become severe. According to Pfeffer (15) and Stark (18) damp localities are suitable for infestation.

The damage so closely resembles that caused by *Sirex* spp. as to be indistinguishable and, moreover, both *Serropalpus* and *Sirex* may be found together in the same timbers (4, 19). Examination at this Laboratory of material infested by each insect has confirmed the absence of distinguishing diagnostic features in the tunnels and frass, but it is of interest to note that according to Stark, Varshalovich described differences between the tunnels of the two genera. Stark apparently saw only the manuscript of this paper, which seems not to have been published. From data at present available it is not possible to determine the relative importance of *Serropalpus* and *Sirex* as economic pests. Only Dominik (4) appears to have investigated this matter, and he came to the conclusion that in the Beskid area of Poland *Sirex* was much the more important, although *Serropalpus* caused considerable damage.

RECORDS OF OCCURRENCES IN THE UNITED KINGDOM

During the period September 1949–September 1953, seventeen inquiries concerning *Serropalpus barbatus* were dealt with at the Forest Products Research Laboratory, samples of timber in which the insect was found or specimens of larvae or beetles being submitted for identification. During the same period twenty inquiries involved *Sirex* wood-wasps of various species and, in addition, a number of samples of wood damaged by *Serropalpus* or *Sirex* were examined, but in the absence of insects and distinguishing features between the tunnels of both no closer identification of the cause of the damage was possible.

The table on page 71 summarizes the information available from the inquiries in which *S. barbatus* was identified.

It will be noted that most of the records are either from silver fir (*Abies alba*) or from an unidentified species of fir (*Abies* spp., possibly *A. alba*). Commercial consignments of Yugoslavian whitewood are likely to consist of a mixture of silver fir and spruce. On the other hand, *Sirex* spp. records concern a much wider range of softwoods and only two were from Yugoslav whitewood and one from *Abies* spp. The records of *S. barbatus* are, with one exception, from Yugoslavian timber (see footnote to table), whereas timber infested by *Sirex* spp. came from several countries. These occurrences of *S. barbatus* seem to be associated with an increased importation of whitewood from Yugoslavia since the Second World War. Inquiries received from different places in England, Scotland, and Wales concerned timber either in timber yards or recently put into service. The fifteen records regarding the emergence of *S. barbatus* range from June to October (one damaged specimen received in November may have emerged earlier), but most of them are for July: the larvae have been found at all times of the year.

DISCUSSION

It seems probable that in this country damage to imported timber caused by *Serropalpus barbatus* may have been attributed to *Sirex* spp. because of the impossibility of distinguishing between these two types of insect attack. Even on the Continent, where *S. barbatus* is recognized in forest insect literature, it is likely to be seen less often than *Sirex* owing to its nocturnal habits, and so the damage caused may sometimes be incorrectly identified. It is of interest to note that, over a period of four years, Forest Products Research Laboratory records of the occurrence of *S. barbatus* in this country are mostly from *Abies* spp. from consignments of Yugoslav whitewood, whereas very few inquiries concerning *Sirex* spp. damage in this timber have been received. It would, however, be unwise to conclude at this stage either that *Abies* spp. is a timber more suitable to *S. barbatus* than *Sirex* spp. or that *S. barbatus* is the commoner in Yugoslavia. Over this period the somewhat greater number of records of *Sirex* spp. has been from a variety of softwoods from several countries, which supports the evidence from the literature that *S. barbatus* is limited to a more restricted number of host trees.

There is no evidence that *S. barbatus* will become established in this country and, in view of the occurrence of records extending back over 60 years, such a possibility may even be regarded as unlikely. There is, however, no reason why

Records of Serropalpus barbatus *received at Forest Products Research Laboratory September 1949 to September 1953*

Date of inquiry	*Timber and origin**	*Specimens submitted*	*Location and damage*	*Remarks*
9.9.49	*Abies* spp. (origin unknown)	1 adult 1 immature adult	Somerset (1 board)	..
18.10.50	Unknown	1 adult	Yorkshire (extent unknown)	..
29.6.51	*Abies* spp. (origin unknown)	1 adult 1 small larva	Glamorgan (member in house)	..
19.9.51	Silver fir (*Abies alba*) (Yugoslavia)	2 larvae (living)	Lanarkshire (flooring)	Exit holes through linoleum appeared between July and September and possibly later
28.1.52	*Abies* spp. (origin unknown)	1 larva (living)	Hampshire (extent unknown)	..
22.3.52	Species unknown (Yugoslavia)	3 larvae	London (flooring)	2 larvae beginning to pupate. Exit holes present
2.5.52	Silver fir (*Abies alba*) (Yugoslavia)	1 larva	Staffordshire (in parcel of boards in timber yard)	..
15.5.52	Silver fir (*Abies alba*) (Yugoslavia)	1 larva (dead)	Warwickshire (1 board in parcel in timber yard)	..
7.7.52	Unknown	1 adult	Herefordshire (floor boarding)	..
11.7.52	Unknown	1 adult (living)	Stirlingshire (floor boarding)	Exit holes penetrating linoleum
16.7.52	*Abies* spp. (origin unknown)	2 adults	Ayrshire (stair stringer)	Mixed infestation with *Sirex gigas*
23.7.52	'Whitewood'† (species not identified) (Yugoslavia)	2 adults	Hampshire (in parcel of boards)	..
14.8.52	Species unknown (Yugoslavia)	2 adults (dead)	Glamorganshire (floor boarding)	3 other houses also affected. Linoleum and carpets penetrated
21.11.52	Silver fir (*Abies alba*) (origin unknown)	Larvae	Yorkshire (2 floor boards)	..
26.11.52	'Whitewood'† (species not identified) (Yugoslavia)	1 adult	Surrey (1 board in timber yard)	..
7.7.53	Unknown	1 adult	Suffolk (member in flush door)	..
7.9.53	Species unknown (Sweden)	Larvae (living)	Warwickshire (floor boarding)	..

* Origin designated in trade description.

† 'Whitewood' (Yugoslav), a trade name usually for mixed parcels of *Abies alba* and *Picea abies*.

imported timber which is infested may not be exported in the form of packing-cases or manufactured articles to other countries where conditions might be more suitable.

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REVIEWS

Japanese Larches at Dunkeld, Perthshire. A Study in Variation. By J. D. Matthews. Forestry Commission, Forest Record No. 25. Her Majesty's Stationery Office, 1954. Pp. 23 with 9 photographs. 2*s.* 0*d.* net.

Review by C. Syrach Larsen

ON a beautiful day in the spring of 1937 I was busy carrying out controlled self-pollination on a selected Japanese larch. I wanted personally to carry out the pollination, and I had personally selected the Japanese larch which I regarded as having an especially nice form and suitable large cones. The material was planned to be the basis of some work with inbreeding. I was exceptionally careful; none the less I proved to be very wrong indeed. The offspring (S. 280) are now in their way a very interesting collection of plants with a height of about 7 metres. They have been carrying cones for a number of years, and the variation from tree to tree is so great that there is little doubt that the tree selected as a Japanese larch was in fact a *Larix eurolepis* (*L. leptolepis* × *L. europaea*)! This experience and others have taught me how difficult it is to distinguish some Japanese larches from hybrids. The probable reason is that we in Europe have too little knowledge of the variations within the Japanese larch itself.

Mr. Matthews's study is therefore of particular interest. No doubt Japanese larch, European larch, and their hybrids are of great importance to forestry. It is evident, however, that both in Great Britain and on the Continent the larches in cultivation represent a peculiar mixture. There is immense variation both from crop to crop and from tree to tree within one stand. From the forester's point of view by no means all are of good timber form and we foresters should aim exclusively at planting to produce valuable timber. That is the whole object of forest tree breeding, and in order to attain that object we must first and foremost carry out our analyses of the material to be used very thoroughly indeed. Mr. Matthews's analysis might be thought very strange and much too detailed. That is by no means the case. Only by very thorough examination of the material and by classification of the qualities likely to be transmitted will it be possible to select individual trees from which to breed.

In the case of Japanese larch, it is natural to begin with the classic trees in Dunkeld Park. It is a great advantage that when planted they were widely spaced and have grown under favourable uniform conditions, so that the present phenotypes can be regarded as comparatively expressive of the genotypes of the individual trees. It is, however, a little curious that the first and the last tree in the row are the smallest ones of the collection. In all there are four trees which hold only half or less than half of the volume of the largest tree. This is a considerable variation, and it is the variation factor which is of the greatest importance in forestry. The tree with the widest crown is only number three as regards volume and the tree that Matthews terms 'the best tree' is only number four in that respect. Furthermore, one gets a clear picture of the considerable variation in branching, habit, bark, foliage, cones, &c.

When comparing the eleven cones shown in photograph 3 with figures in Dallimore and Jackson, *Handbook of Coniferae*, 1948, p. 364; W. J. Bean, *Trees and Shrubs Hardy in the British Isles*, 1951, vol. ii, p. 195; and with L. Beissner, *Handbuch der Nadelholzkunde*, 1909, p. 308, I get the impression that in these manuals the cones shown as typical of Japanese larch are somewhat different from most of the eleven cones from Dunkeld. Several cones from

Dunkeld are rather slender, and it was this fact that caused me to say in the work[1] referred to by Matthews: 'The variation between these trees is such that mutual crossing might well be imagined to result in some plants with such combination of characters that, with regard to habit and shape of cones, they might correspond to the description of these characters given in the case of the hybrid.' The Dunkeld larches we are discussing may, however, well be pure Japanese larches of another type than generally described. We have still much to learn about the variation of this species. The cone is only one thing. Foliage, bark, branching, habit, and volume production are just as important.

We know yet far too little of the interaction of these characters and of their utilization in raising valuable types of timber trees. It is a good start to demonstrate the variation, and we wish the Forestry Commission success in further investigations in this important branch of forest tree breeding.

Forestry. By H. G. Champion. No. 226. The Home University Library of Modern Knowledge. Geoffrey Cumberlege, The Oxford University Press, Amen House, London, E.C. 4. 1954. Pp. 230. Price 6*s*. net.

Review by W. A. Robertson

TO those foresters who are in the flower of their pension it is a welcome sight to see forestry figuring in such a popular series as the Home University Library. We look back on a time when books on forestry were books of devotion written for the devout. Here is something that the unconverted and the unbeliever can read with profit and with ease.

Professor Champion has covered the whole subject comprehensively, simply, and lucidly, choosing his illustrative examples from all over the world. Specialists may pick on points here and there to argue about, but they do not affect the general theme. We know of no better introduction to the subject.

As it is the duty of a reviewer to find some flaws, here are one or two which may be due to the draft not having been read by a layman. Thus the author leaves the reader to find out for himself that it is the American and not the English 'billion' that is being used. One cannot help wishing that a less ambiguous term such as 'milliard' were in general use to denominate one thousand million. On page 57, is not 'nagana' the usual name for the cattle disease? On page 68, we are not told what unit area receives the two tons of dead leaves, &c., though it is presumably the acre specified on page 22.

But these are really trifles and the final verdict on the book must be that it is a first-class work.

[1] Larsen, C. Syrach, 'The Employment of Species, Types and Individuals in Forestry', *Royal Veterinary and Agricultural College Year Book*, Copenhagen (1937), p. 88.

NOTICES

Drought Crack of Conifers. By W. R. Day. Forestry Commission, Forest Record No. 26. 1954. London, Her Majesty's Stationery Office. Pp. 40, photographs 9. Price 2*s.* 6*d.*

AN investigation into the spiral cracking of the main stem in conifers mostly in spruce of which drought was shown to be the cause. The Record is therefore concerned firstly to present the evidence available with regard to drought crack including climatic conditions during the very dry summer of 1947 when the cracks first occurred, i.e. during and towards the end of the period of formation of the annual ring, and secondly to discuss shortly some aspects of the subject which are of current interest. As the author says, the importance of drought crack goes far beyond the few trees affected and it is in the discussion that follows that the greatest interest will be found. This cannot be covered fully in a short notice, but Mr. Day's views are well known and two extracts from the discussion will serve to show the lines along which he is thinking. For instance on page 14 he says:

> 'The implications of the abnormal elements in structure are that the trees have grown in a climate in which their constitutional needs for the production of strong well-developed wood, with normal ring-endings, have remained unsatisfied.'

and again on page 34:

> 'It is also presumably an indication of a poor fit physiologically between the tree and its environment.'

The wood of the cracked trees so far examined has consistently been of light, poor structure. Sites on which cracking occurred were characterized by a shallow depth of soil favourable to root development but on which the needs of trees which have grown to form high canopy cannot be met during periods of prolonged drought. The tendency in selecting sites for planting to regard spruce as a shallow-rooted tree irrespective of soil conditions may have some bearing on this.

A list of fungi isolated in the heartwood of spruce in high canopy affected by crack or uninjured among trees so affected is given and the suggestion tentatively made that the evidence from the Radnor forest race plots supports the suggestion that poor climatic fit has some bearing on the matter.

1954. Forest Seed Directory. Food and Agricultural Organization of the United Nations. Rome, Viale delle Terme di Caracalla. Pp. 110. Price not stated.

THE Directory gives an address list of agencies in countries prepared to provide seed and a list of species available. It is pointed out in the Note of Introduction that the listing of commercial dealers is not complete. It is further stated that, for the 1955 edition, only those commercial dealers who agree to supply certificates of quality and origin and whose names are submitted, with seed lists, by member governments, will be included. The form of certificate of seed quality and of origin and a form of consignment are given, but we were unable to find the abstract from the International Seed Testing Association rules said to have been included.

Some note on viability would be useful. We observe that only Viet-Nam is prepared to

undertake the dispatch of the perishable seeds of *Hopea*, *Dipterocarpus*, and *Shorea*. Apart from well-known cases such as Teak, Cassia, and Eucalyptus, it is interesting to see how some species have spread from their countries of origin. *Gmelina arborea*, for instance, is available from Sierra Leone and Rhodesia, while *Albizzia lebbek* (a useful nurse tree) can be had from five different parts of Africa. But all these trees have readily viable seed.

Forestry Abstracts Coverage List. Food and Agriculture Organization of the United Nations. Rome, Viale delle Terme di Caracalla. 1953. Pp. 180. Price 7*s.* 6*d.*

THIS reference list was prepared by the Commonwealth Forestry Bureau from its card index of the literature forming the basis of its quarterly publication, *Forestry Abstracts*, and is the first to be published. It forms a comprehensive and well-tested collection of publications carrying material of significance to forestry. The Sixth Session of the F.A.O. Conference, Rome, 1951, urged co-operation between international agencies concerned with disseminating bibliographical information and providing technical reference material on agriculture and allied subjects. The reference list is published in accordance with the spirit of the resolution adopted by the Conference.

The list is in two parts, main and subsidiary, each arranged alphabetically under countries. The list supersedes all previous lists issued by the Commonwealth Forestry Bureau, Oxford, and it is requested that any errors or omissions be reported direct to the Bureau.

Forest Products Research and Industries in the United States. By W. W. Varossieau. J. M. Meulnhoff, Amsterdam, 1954. Hfl. 45. Pp. 796 with 64 photographs and numerous figures and tables.

DR. VAROSSIEAU, who was wood technologist in the Forest Products Research Division of the National Council of Applied Scientific Research in the Netherlands, visited the United States under the auspices of the Technical Assistance Branch of the European Recovery Program after the war and this book, which is described by E. S. Harrar in his review in the August 1954 number of *Journal of Forestry* as representing 'a prodigious amount of meticulous effort', is a result of this visit. In recent years forest products industries in Europe have been faced with a severe shortage of timber, and the author was appointed to study this problem in the United States and to determine to what extent American methods for the production, harvesting, processing, and conversion of timber might be adopted in Europe. The book is designed to appeal not only to specialists in the field, who require the technical details and sources of information for use in the improvement of processes and products; but also to persons who, though interested in the overall picture of the wood industries in the United States, have no technical background. The result is a reference book of very considerable value. The conclusions arrived at are listed under nineteen separate headings including one heading giving instances of various types of processes and equipment developed in Europe that are being considered for application in the United States and one heading giving a warning that, whereas in the United States it nearly always pays to mechanize to save manual labour, this may not always be the case in Europe. Commenting on this last, the American reviewer quoted above remarks that it was a pity that those planning Dr. Varossieau's itinerary should not have included the south-eastern United States where the forests exhibit much greater similarity to European forests than do those of the West Coast, and where industry has been geared to the use of the smaller, and often more defective, logs these forests produce.

Timber, Its Structure and Properties. Third, Revised Edition. By H. E. Desch. London, Macmillan and Co. Ltd., 1953. Pp. 350 with 65 plates and 46 text figures. Price 25*s.* net.

THE two previous editions of Dr. Desch's book were reviewed in *Forestry* by B. J. Rendle in vol. xii, No. 1 and vol. xxi, No. 2. In the third edition the sections on the 'Classification of Trees and Nomenclature of Timbers' have been rewritten to clarify the difficulties that non-specialists experience with timber names. To meet the need of students preparing for trade examinations, a section on the microscopic features used in the identification of softwoods has been added to Chapter II. The chapter 'Defects in Timber' has been rewritten and expanded. Fungi and insects each have a chapter to themselves, and a new chapter 'The Eradication of Fungal Infection and Insect Attack' has been added after the chapter 'The Preservation of Wood'.

Mechanical Properties of Wood and Paper. By W. W. Barkas, R. F. S. Hearmon, and H. F. Rance. Edited by R. Meredith. North Holland Publishing Company, Amsterdam, 1953. Pp. 298 with many figures and tables. Price Hfl. 25.

THIS monograph, published under the general title of *Deformation and Flow: Monographs on the Rheological Behaviour of Natural and Synthetic Products*, is essentially a contribution to our knowledge of the mechanical properties of fibrous materials. In the part dealing with wood an account of the more fundamental work on the rheology of wood is given, with special emphasis on the thermodynamic aspects of the relations between the hygroscopic and the rheological properties of swelling materials. The treatment of the part concerning paper aims to satisfy two types of reader: the scientific investigator of the mechanical properties of materials and he who is more directly concerned with the making and using of paper.

The Strength Properties of Timber. By F. H. Armstrong. Forest Products Research Bulletin No. 28. London, Her Majesty's Stationery Office, 1953. Pp. 41. Price 2*s.* net.

THIS bulletin presents strength data from standard tests, made at the Forest Products Research Laboratory, Princes Risborough, over the past 25 years, of 122 native-grown and imported softwoods and hardwoods.

A brief description is given of the methods of test used for small clear specimens of timber, as well as explanations of the various strength properties determined from these tests. The influence of several factors upon strength is discussed and the relationships between the strength properties and specific gravity, or density, are examined. Comparisons of species and the assessment of their utilization value are afforded by means of diagrams. A comprehensive table of strength results for all the species of timber tested is appended.

The Strength Properties of Plywood. Part I. Comparison of 3-Ply Woods of a Standard Thickness. By W. T. Curry. Forest Products Research Bulletin No. 29. London, Her Majesty's Stationery Office, 1953. Pp. 10. Price 1*s.* 3*d.* net.

THE methods described in this bulletin are used to determine the bending, tension, compression, shear, and impact strengths of plywood. The results obtained from tests made on twenty-five different species of $\frac{3}{16}$-inch 3-ply wood are included. These results apply only to the type and thickness tested and cannot be used for any other type or construction.

Mechanics of Sawing: Band and Circular Saws. By P. Harris. Forest Products Research Bulletin No. 30. London, Her Majesty's Stationery Office, 1954. Pp. 30. Price 1*s.* 6*d.* net.

THE cutting action of band-saw and circular-saw teeth is analysed and relationships are established between the dimensions of the wood removed and the conditions of sawing. A theory is formulated concerning the resistance offered by the wood to the passage of a saw tooth. Equations are derived for the power demand and energy consumption in sawing, in terms of the speed, shape, spacing, and relative sharpness of the teeth and the strength properties of the wood. The influence of the cutting conditions on the rate of tooth blunting is also studied.

The Performance of Circular Plate Ripsaws. By H. J. Endersby. Forest Products Research Bulletin No. 27. London, Her Majesty's Stationery Office, 1953. Pp. 20. Price 1*s.* 9*d.* net.

PERFORMANCE has been related to (1) feed speed, (2) depth of cut, (3) hook angle, (4) number of teeth on the saw, and (5) density of timber cut. Particular attention was paid to saws having relatively few teeth, and evidence was obtained which indicated that their use depended on suitable operating conditions. The behaviour of sawdust in the vicinity of the gullet was studied with the aid of high-speed photography, and an attempt made to correlate the amount of sawdust retained in the gullet to particle size.

CORRIGENDA

The following corrections should be made in the review by Dr. E. W. Jones of Mr. J. M. B. Brown's *Studies on British Beechwoods* which appeared in *Forestry*, xxvii, number 2. Near the foot of page 153, for (61° C.) read (–6·1° C.). In the penultimate paragraph of the review, a bracket has strayed out of place and the last sentence should read 'one should be critical even in assuming that the formation of mor is necessarily an evil (especially when humus on chalk soil is to be included under that definition)'.

We regret, too, that at the head of the review, Dr. Jones's initials were put in the wrong order.

SOCIETY'S AND OTHER NEWS

AWARD OF THE SOCIETY'S MEDAL TO H. M. STEVEN

The Society's very proper and unanimous desire to present its Medal to Professor H. M. Steven was realized at the 27th Annual General Meeting at Bognor Regis on 22nd September 1954, when the medal was handed to him by the retiring President of the Society, Mr. A. H. Gosling, amid general applause.

MEETING AND EXCURSIONS FOR 1955

It has been decided to hold two excursions in 1955. The earlier one to be of the usual length and to take place in the Lake District in the week beginning 16th May and the later one to be in Denmark for a week in the second half of September. The excursion to Denmark is limited to 30 and it may therefore be necessary to ballot for places. The 28th Annual General Meeting will take place during the earlier excursion and consequently nominations for office bearers and for councillors will be required by the Secretary earlier than usual, probably by 31st March.

THE 1954 EXCURSION

This was held in brilliant weather in West Sussex from 20th to 24th September, and about 80 members attended. The woods visited lay within the area bounded by a line running through Chichester, Arundel, Petworth, Fernhurst, and Midhurst. Mr. James Macdonald was in charge, and the Society owes much to him and to several others in the Forestry Commission for the perfection of the arrangements made and is indebted also to the National Trust, The Rural Industries Bureau, and to the owners of the estates visited for their interest, help, and hospitality. The three days were mainly taken up with the many aspects of the silviculture and management of beech on the chalk, oak on the Weald clays and, more briefly, with chestnut on the Greensand. In addition some very interesting developments were seen in the making of roads. The notes below, necessarily brief owing to limitations of space, are taken mainly from the excellent ones provided for the meeting.

Geology and Soils. A salient feature of this well-wooded area is the escarpment of the chalk crossing it from west to east and reaching an elevation of 700 feet.

To the north, the Weald Clay yields retentive gleyed soils. The steep scarp slopes of the Lower Greensand yield friable, well-drained sands or sandy loams which, sheltered from south and south-west, are valuable for forestry. South of the scarp, the Greensand dip slopes are for the most part covered with deep, friable, well-drained soils which under the primeval oakwood show mull humus and a brown earth profile but, where reforestation has been carried out, mostly with chestnut, pines and European larch, there is a tendency to soil degradation and the formation of mor.

Lower and Middle Chalk form the greater part of the main escarpment slopes and the dissected plateau south of the escarpment includes a wide range of chalky soils. While it will be conceded that the underlying chalk is everywhere—or nearly everywhere—influential, it is clear that local variations in soil depth, calcium carbonate content, and reaction depend a great deal on the vegetational cover in the present and recent past.

Among Post-Cretaceous deposits, the remarkable Slindon Park beechwood on acid gravels of Quaternary age merits notice.

Cowdray Park. Verdley Wood lies on heavy Wealden soils which normally carry oak forest and coppice, a type of broadleaved woodland which, when cut, often creates a grave problem. Here successful plantations of Douglas fir (1926. Quality class I to II) and Sitka spruce (1917. Quality class I) have been made, demonstrating an effective way of dealing with such understocked woodland. At Vining Rough on the same estate but on the Greensand, the growth of Corsican pine and Scots pine on acid soils was demonstrated and the natural regeneration of the latter discussed. Members also inspected some areas of chestnut coppice worked as simple coppice on a rotation of 10 to 12 years mainly for fencing and visited The Fernhurst Chestnut Fencing Company's yard. Finally the famous yews in the Close Walks at Midhurst were seen.

Slindon Forest. The 800 acres of Eartham Wood consisted when acquired in 1938 of relatively dense birch and ash scrub on freely draining soils of high quality overlying the Upper Chalk which is covered in some places with a deposit of Clay-with-flints. The wood has been restocked mainly with beech. Halts were made to see the beech planted out under the canopy of birch and ash and to see a shading experiment for beech where the indications are that on this site, a Rendziniform soil over chalk, with a gentle south facing slope, the form of the beech benefits from shade amounting in summer to a reduction to 30 per cent. full light. A halt was also made to see one year seedling beech successfully introduced under a canopy of birch.

At Slindon (National Trust) the famous stand of beech was inspected. The crop is growing on an old raised beach resting on the chalk. The acid soil is a deep, very flinty, brown loam, sandy near the surface but becoming a clay loam at depth. The crop was heavily thinned during the war when counts on stumps revealed a range of ages from 160 to 240 years. The owners are now attempting to regenerate the crop naturally. This stand of beech is referred to in Forestry Commission Bulletin No. 20, *Studies on British Beechwoods*, by J. M. B. Brown. A number of trees in the crop have been selected by the Genetics Section of the Forestry Commission as a foundation for a seed orchard of beech.

Arundel Forest. In the Houghton Block on the dip slope of the South Downs some 400 acres of old beechwood felled during 1939–45 have been cleared and replanted with beech on the shallower soils and with oak or a mixture of oak and Norway spruce on the deeper Clay-with-flints with groups of ash in some places. The remainder of the block consists of old woodland and shelterbelts which the present policy is to retain for as long as possible to preserve the character of the district.

Goodwood Estate. In Singleton Forest a dense crop of beech 90 to 120 years old was inspected and discussions on thinning practice took place. Drovers Estate (National Trust) and the arboretum at West Dean were also seen.

Technical Discussion. The subject chosen for the discussion on the last evening was 'The Cultivation of Beech with special reference to Chalk Lands.' The discussion was opened by Mr. Sangar, who suggested that the policy of planting beech rather than its silviculture be discussed and a useful if somewhat indeterminate debate followed. Among those who took part were Messrs. Hummel, Dalgleish, Penistan, Hodson, Garfitt, Laurie, Brasnett, Edlin, Dr. Wilson, and Messrs. Workman (father and son), Hampson, Evans, Macgregor, Long, Hutt, McGarva, Steven, Cameron, and Hiley (Chairman). One thing seems clear. If we are to grow beech other than for sentimental reasons, we must regenerate surely, grow the trees quickly, use marketable nurses, and keep meticulous records.

[*continued from inside front cover*

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